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Final Report

HIGH VOLTAGE POWER LINE SITING CRITERIA

Volume II. Application of Prediction Technqiues to Communication and Electronic Sites

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R. T. Harrold

Westinghouse Electric Corp.

TECHNICAL REPORT NO. RADC-TR- 66-606
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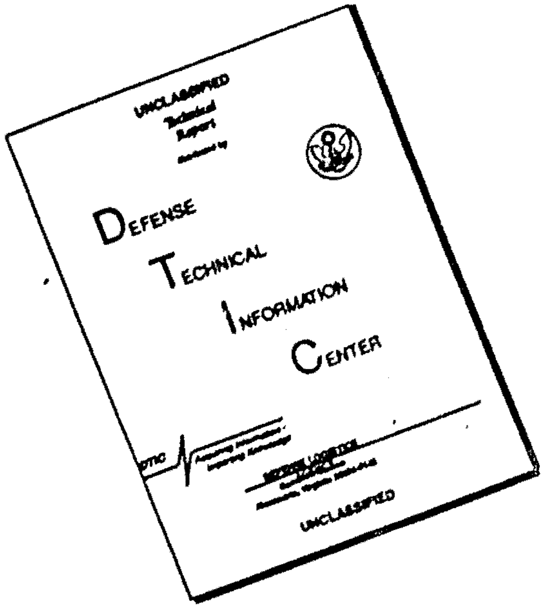

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HIGH VOLTAGE POWER LINE SITING CRITERIA

Volume II. Application of Prediction Techniques to Communication and Electronic Sites

W. E. Pakala
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Contents - Vol. II

LIST OF FIGURES - VOL. II

List of Figures - Contd.

List of Figures - Contd.

Vol. II - Application of Prediction Techniques to Communications and Electronic Sites.

1. Introduction

1.1 This part of the report briefly summarizes the pertinent results of tests reported in Volume I, and, together with data in unpublished reports by the authors and in published literature, develops a radio noise prediction technique for radio noise from power lines to be used for siting communication areas.

As detailed in Volume I, radio noise levels for power lines rated below 110 kV are generally very low except when gap-type sources are present. Power lines rated 110 to 345 kV are usually free of gap-type sources, and the radio noise from them is usually due to conductor corona, and is a function of the conductor size and its electric gradient at the conductor surface. Therefore, the two voltage ranges, 2.4 to 70 kV and 110 to 345 kV, will be considered separately.

1.2 Instrumentation Considerations

1.2.1 Many of the measurements reported here have been made with the peak detector, using the manual slide-back technique. The measured values are, therefore, for a pulse repetition rate of only about 0.5 pulses per second. However, Figure II-1 shows that the reading is not too sensitive to the number of pulses allowed by a particular position of the slide-back, and will be within a few dB of the exact peak reading for a considerable number of allowed pulses.

1.2.2 For the low-frequency measurements, 60 cps to 15 kc/s, comparisons of power lines are made on the basis of electric field measurements, since the strength of the magnetic field in the vicinity of a line is a function of the current, which will be continually varying with load. (See Appendix VI, Vol. I, Low Frequency Measurements 60 Cycles/Sec. to 15 Kilocycles/Sec.)

1.3 Cautions

1.3.1 The noise discussed here is considered to be from the power lines themselves. No study of electric power utilization devices was made, and only that device noise which may have been present on the power lines measured inherently enters into the results. The user of these data is therefore cautioned that device noise may be a factor in a particular installation.

Because of possible effects of utilization devices connected to low-voltage lines, the user of this method of prediction should be cautioned that certain harmonics may be more pronounced than would be predicted by Fig. II-3. The procedure to be followed has been based on levels from low-voltage lines in suburban areas. Where the lines supply power to industrial or light-industry areas, higher 60 cycle harmonics may occur. (Note Table 1. of Appendix IV, Vol. I.)

1.3.2 The effect of gap-type noise sources has not been factored into the prediction method. Although the field results of this study do not support this, the probability of such sources being present is higher on low-voltage lines unmaintained or of old construction, and may invalidate the prediction results, particularly in the higher part of the frequency range. Levels from such lines are very variable and unpredictable.

However, present line design and construction practices recognize the problem of radio noise, and attempt to reduce or eliminate sources of radio noise.

2. Prediction for Power Lines from 2.4 to 70 kV

2.1 Electric Field Strengths for Frequencies of 60 cps to 0.015 Mc/s.

2.1.1 Levels measured in this frequency range are predominantly at the harmonics of the 60-cycle, which the measured data has indicated at 200 feet to drop off approximately inversely as the ratio of the frequency squared (40 dB per frequency decade) to about 2000 cps where the levels may level off because of gap-type noise sources or for other unknown reasons. The field strength at 60 cps is proportional to the line voltage, but is not uniquely determined by this voltage, depending also on conductor phase spacing, height, and configuration. Fig. II-2 gives a summary curve of the 60-cps electric field at 200 feet for the lines measured and reported in Volume I and Appendix VI, Vol. I., such lines being of constructions typical for these voltages. Conductor heights, spacings, and configurations for the lines tested are given in Table II-1. Should there be a considerable difference for the particular line for which the prediction method is desired, measurements should be made near this line, or a value should be calculated from electrostatic principles (Appendix II, Vol. I.).

At these low frequencies the field (being the "near field") falls off theoretically as the inverse of the distance cubed. Figure II-4 gives this theoretical distance correction from 200 feet.

2.1.2 Example of prediction of level of 5th harmonic of 60 cps at 2000 feet from line for a 44 kV line of construction similar to Table II-1

<u>Step 1</u>. Enter Fig. II-2 for the voltage of the line and find the estimated 60-cycle field at 200 feet.

For 44 kV, this is 132 dB above 1 μV/m. (Point A).

<u>Step 2</u>. Find from Fig. II-3, the correction for the particular harmonic.

Harmonic frequency = 5 x 60 = 300 cps.

For 300 cps, correction is -28 dB (Point A).

Table II-1
Phase Conductor Heights and Spacings for Lines Tested

Line-to-Line Voltage (kV)	Height (Feet)	Spacings (Feet)	Configuration
8	33	3.6-3.6	Flat
46	35	5-5-5	Triangular
69	36	12.5-12.5	Flat
161	61	20.7-20.7	Flat
244	56.5	28-28	Flat
345	46	26-26	Flat

Step 3. Correct 60-cycle level by harmonic correction.

Level at 200 feet for 300 cps = 132 - 28 = 104 dB.

Step 4. Correct harmonic level at 200 feet to specific distance by entering Fig. II-4 at that distance.

Corrections to 2000 feet is -60 dB (Point A).

Level at 2000 feet for 300 cps = 104 - 60 = 44 dB above 1 μv/m.

2.2 Field Strengths for Frequencies above 0.015 Mc/s to 1000 Mc/s

2.2.1 Power Lines from 2.4 to 70 kV

Power lines in the 2.4 to 70 kV range are considered free of conductor corona and the only radio noise sources will be electrical discharges between unbonded or floating metal parts, corroded hardware parts, neutral conductors and ground wires and pole guy wires and discharges or corona in pole top apparatus, which is defective or damaged, or improperly designed, mounted, or used, such as arresters, fuse cutouts, bushings, and line insulators.

Thus, there are three important conditions which could be considered with respect to communications siting near 2.4 to 70 kV lines.

These are:

Radio noise level with the line in good condition; that is, no local gap-type sources and no multiplicity of sources such as insulators on every pole.

Radio noise level with gap-type source on line or distributed sources near proposed critical area.

Conduction by line of radio noise from substations and other lines and sources such as utilization devices or vehicles not directly connected to any high voltage line.

In order to protect the communication site 100% of the time it would be necessary to consider the worst condition. This is expected to be, for continuous radio noise, a gap-type discharge on the line and near the communication site. From the measurements reported the worst case on lines below 70 kV is shown in Fig. 33 of Vol. I. It is not possible, without a large amount of data on the more powerful sources, to predict the highest possible continuous or intermittent radio noise level. The highest transient or intermittent levels from the line will occur during lightning strokes to the line, and during opening or switching of the line or switching some higher voltage adjacent line.

2.2.2 The measured magnitudes of radio noise in the frequency range 0.015 to 1000 Mc/s were quite low for the low voltage lines (below 70 kV), except where a radio noise source was found near the test location. Generally, such noise sources result in high radio noise levels but they can be found and reduced or eliminated.

There appears to be no correlation of radio noise levels with line voltage for the low voltage lines, nor do the levels increase in foul weather. Therefore, the prediction technique for low voltage lines will be based on the fair weather frequency spectrum from a 4.16 kV line with no known sources, which had radio noise levels equal to or higher than any of the other low voltage lines tested. Fig. II-5 gives the frequency spectrum for use in the prediction, derived from the maximum measured values for this 4.16 kV line, (Fig. 33 of Vol. I), corrected to a reference distance of 200 feet according to Fig. II-34. Fig. II-34 shows the calculated corrections that may be made from measurements at 50 feet to a distance of 200 feet.

2.2.3 It is assumed that the permissible radio noise level at the communication site for any required frequency is known. The prediction technique requires an estimation or measurement of the radio noise level at 200 feet from the power line for the frequency or frequencies of interest.

Step 1. For purposes of estimation, enter Figure II-5 for the frequencies of interest (for example, at 61.44 Mc/s, with a corresponding level at 200 feet of 48 dB peak above 1 μV/m/McBW, Point A).

Step 2. The total lateral attenuation required to produce a noise level no more than that permitted is to be determined. For example, assume the permitted level is 28 dB peak above 1 μV/m/McBW.

The lateral attenuation, or path loss, must be

$$dB_a = dB_s - dB_r$$

where dB_a is total lateral attenuation; dB_s, the line noise level at 200 feet from Step 1, and dB_r, the permissible noise level at the communication site.

intermediate frequencies, and Point A corresponds to the break point for the above example. Thus, if 60 dB path loss is required at 45 Mc/s, a distance of 8,000 feet is required (Point B), determined by entering at Point A and following down the Inverse-Distance-Squared line to -60 dB.

2.2.5 If the attenuation should be beyond that of the applicable curve, the added required distance beyond that of the curve may be obtained from the inverse-distance-squared relationship. Maximum attenuation path-loss shown on this figure is 70 dB. As an example of the extrapolation, assume for the previous example 80 dB path loss is required. For Fig. II-17, 61.44 Mc/s, the path loss curve for 40-foot antenna height and 35-foot conductor height runs out to 27,000 feet (Point D) for a path-loss of 70 dB. An additional attenuation of 80 minus 70 dB, or 10 dB, is required. Read up from the distance scale at the distance intersection at -70 dB (here, 27,000 feet) by the required additional attenuation (10 dB), according to the vertical scale (Point E). Follow a parallel to the nearest curve back to the horizontal distance axis (Point F) and read the intersection (46,000 feet). Thus, for the example for 80 dB path loss, it is necessary to go 46,000 feet away from the line.

2.2.6 Horizontal dipole antenna orientation is not considered as a factor in the general prediction technique. Therefore, the calculated curves for path loss Figures II-14 to -25, are given only for the dipole antenna perpendicular to the line.

2.2.7 Receiver antenna height and polarization has some effect on noise levels received, particularly in the higher range of frequencies. Results of the measurements reported in Appendix V, Antenna Comparisons, made to determine the effect of antenna height indicate that the field strength between 24 and 90 feet may be higher or lower than the field strength measured with an antenna height of 20.5 feet, the height for the data to be used for the prediction technique for 25 to 1000 Mc/s. This variation in field strength, however, depends also on the frequency, the distance from the line, the terrain, and the height of the effective transmitter antenna height (in most cases, the line conductor height). (See Section 10, Vol. I.)

2.2.8 Because of the dependence of antenna height gain on so many factors for frequencies 25 Mc/s and above, where an antenna height correction is desired it is suggested that a value of 12 dB be used in the range of distances where the field strength decreases inversely with distance (about 2000 feet or less). In the range of distances where the field strength decreases inversely with the square of the distance (beyond about 2000 feet) an increase of 20 dB per decade of antenna height is suggested for antenna height correction above 20.5 feet. (See Fig. II-27.)

Example: For a frequency of 61.44 Mc/s, it has been

Then, for the example:

$$dB_a = 48 - 28 = 20 \text{ dB.}$$

Step 3. Select the path-loss curve from Figures II-6 through II-25 corresponding closest to the frequency of interest for the particular antenna polarization. For 61.44 Mc/s with vertical dipole this is Figure II-17. Enter the vertical axis of attenuation at the required path loss from Step 2, and read across to the curve corresponding nearest to the receiver antenna height, say 40-foot antenna height, and 35-foot conductor height for the low-voltage lines, and down to the corresponding distance. For 61.44 Mc/s, Point A, this corresponds to about 1400 feet.

Thus, the site should be located at least 1400 feet away from the line.

2.2.4 Where the frequency of interest is not given by any particular curve of Figures II-14 through II-25 an interpolated curve must be obtained. To obtain this curve requires determining the break point at which the path loss for a given antenna height and conductor height changes from a function of the inverse-distance to that of the inverse-distance-squared. This point may be obtained by interpolation between approximate break points for the bracketing frequencies. Each of these break points is obtained by extrapolating the appropriate curves varying as inverse-distance squared back to the line labeled "Approximate". Example: Assume the path loss is required for 45 Mc/s for a horizontal antenna at 40 feet with a conductor height of 35 feet. Bracketing frequencies are 30.72 and 61.44 Mc/s, for which Figures II-15 and II-16 are applicable for the horizontal dipole. On Fig. II-15, lay a straight edge along the curve corresponding to the antenna and conductor heights of interest. Where the straight edge crosses the line labeled "Approximate" (Point A of Fig. II-15) note the corresponding distance on the horizontal scale. For 30.72 Mc/s the breakpoint (Point A) is about 260 feet; for 61.44 Mc/s (Fig. II-16), it is about 550 feet (Point A). By linear interpolation the breakpoint for 45 Mc/s is

$$PB_{45} = PB_{61} - \frac{61 \text{ Mc/s} - 45 \text{ Mc/s}}{61 \text{ Mc/s} - 30 \text{ Mc/s}} (PB_{61} - PB_{30})$$

or,

$$PB_{45} = 550' - \frac{61 - 45}{61 - 30} (550 - 260)$$
$$= 550' - 253 \approx \underline{330 \text{ feet}}$$

Thus, for 45 Mc/s and the given heights, the path loss out to 300 feet is a function of the inverse distance. Beyond this it may be taken as a function of the inverse of the distance squared. Fig. II-26 has been prepared for the purpose of determining the path-loss for determined that a distance of 6000 feet will be required for the communication site from a neighboring power line, if a receiver antenna height of 20.5 feet is used. The power line conductor heights are 35-feet. The antenna height, however, will be 40 feet. Enter Fig. II-27 for Antenna Height Correction at 40 feet and read 5.8 dB (Point A). Enter Fig. II-17 for 61.44 Mc/s on the line corresponding to the 40-foot antenna height and 35-foot conductor heights at 6000 feet. The attenuation relative to a distance of 200 feet is -45 dB (Point B). This must be increased by the antenna height correction of 5.8 dB, or to -50.8 dB, relative to the level at 200 feet. From Fig. II-17, Point C, corresponding to -50.8 dB, read off a distance of 8300 feet. Thus, the site must be located 8300 feet away for an antenna height of 40 feet.

Calculations here have been performed using a dielectric constant of 30 and a ground conductivity of 20 millimho-meters per square meter, which is representative of values for soil of good conductivity. Attenuation with poorer ground conditions is greater. Should very good conductivity be present, the path-loss curves may be expected to give somewhat greater attenuation than may be experienced, and in these instances, a relationship of attenuation inversely to the first power of distance should be used throughout the distance range.

It should be recognized that for a particular set of conditions of terrain, frequency, etc., that some gain in signal to noise ratio can be obtained from a small antenna height adjustment, and may be necessary under these conditions.

2.2.9 Antenna height effects are discussed further in Vol. I, Appendix IV where the limitations of the path-loss calculations due to antenna height are given in more detail. The calculations of path-loss given here assume a plane earth and neglect the effect of divergence of energy due to earth curvature at the high frequencies, and any reflections from the sky. Although the equations utilized are, strictly speaking, applicable to dipole antennas, they have been shown in this appendix to give adequate results for radiation from long conductors as measured with short antennas. It is also pointed out that the equations are accurate out to roughly 5 miles for 1000 Mc/s.

3. Prediction for Power Lines from 110 - 345 kV

Power lines in this voltage range and to higher voltages than 345 kV will normally have conductor corona, in varying amounts, depending on the conductor gradient and its surface condition. These lines can also have gap-type radio noise sources which will usually occur at the towers and which can over-ride conductor corona radio noise at locations in the vicinity of the gap-type source.

Corona type radio noise may be generated by corona on hardware, burrs and scratches on the conductor surface. Since radio noise is also generated at water drops, snow, ice, frost, dirt, vegetation, insects, it becomes variable, especially in fair weather, and determination of the radio noise level due to corona is based on recording or long time instantaneous measurements.

The technique of predicting power line corona radio noise is essentially a comparison method. A comparison method is necessary because it is not possible to calculate corona type radio noise generation from the presently known physical processes. The amount of data obtained in fair weather on the 110, 138, 244 and 345 kV lines tested during this project is not sufficient to establish the average fair weather level. It can be compared, however, to predicted values obtained from long term data on other lines. The data obtained in rain will be useful and for most locations the most important since radio noise is higher in heavy rain than in fair weather by 17-24 dB, depending on the amount of rain.

In the prediction of the radio noise generation due to conductor corona the following factors will be considered:

The maximum nominal conductor surface gradient, the size and number of conductors per phase, and the nominal three phase voltage of the line. This gradient can be obtained from Fig. II-32, Fig. II-33 or from the curves given in Appendix III of Vol. I of this report.

The change in corona type radio noise generation with conductor diameter in rain. Refer to Appendix I and Fig. II-28.

The change in corona type radio noise generation with conductor gradient. Refer to Appendix II and curves developed and shown on Fig. II-28.

The change in corona type radio noise generation with conductor surface factor. Refer to Appendix I, Vol. I.

The change in corona type radio noise generation with altitude. Refer to Appendix I and Fig. II-28.

These factors will be used to compare the line in question to operating lines for which data is available. From this comparison the frequency spectrum for line in question will be estimated. The correction curves for radius, gradient, etc. will all be referred to a one inch diameter conductor.

The various equations, (see Appendix I, Vol. I) which will be used are as follows:

For conductor diameter change

$$\Delta dB_r = 20 \log_{10}\left(\frac{d_2}{d_1}\right)^{3/2} = 30 \log_{10} \frac{d_2}{d_1} \qquad (3)$$

For difference in conductor surface gradients in kV_{rms}/cm, gm, (use maximum gradient on sub-conductor of bundle conductors).

$$\Delta dB_g = 3.5\,(g_2 - g_1) \qquad (4)$$

For difference in altitude (relative air density = δ) referred to $\delta = 1$

$$\Delta dB = 3.5\left(\frac{g_2}{\sqrt{\delta_2}} - \frac{g_1}{\sqrt{\delta_1}}\right) = 3.5\,g\left(\frac{1}{\sqrt{\delta}} - 1\right) \qquad (5)$$

All of these changes in radio noise for conductors in corona have been plotted on Fig. II-28. The changes in radio noise, as stated previously, are referred to a one-inch diameter conductor with a gradient of 18 kV_{rms}/cm and a relative air density equal to 1. For lines with different size conductors corrections can be made by means of Fig. II-28 and the line radio noise curves on Fig. II-29 adjusted up or down depending on the size of the correction in dB. After this has been done the procedure is the same as described below in the following section.

3.1 Siting Distances from Line for Conductor Corona

The radio noise levels to be used in fair weather and to be used in heavy rain are on Fig. II-29. The fair weather values are based on the average of published values measured near several 345 kV lines of the Bonneville Power Administration and at the Apple Grove and EHV test Projects. The curves for rain are based on rain data on test lines and these curves are for heavy rain.

Excepting for very dry areas it is suggested that the curves for heavy rain be used in the prediction and determination of the distance from overhead power lime to the communication site. For dry areas great care is required because dirt and dust can collect on the conductor and the radio noise level may approach the rain conditions for other areas. Also it is indicated by experience that after rain lines have less noise probably because part of the dirt and dust etc. are washed off the line conductors.

Fig. II-29 also shows a sample radio noise limit curve for the communication site. The required distance to the communication site is obtained by means of this curve, the radio noise level curves corrected for line height, and the lateral attenuation curves, Fig. II-6 to II-25 as was done in Steps 1, 2 and 3 for low voltage lines, Sec. 2.2.3.

This has been done for the limit curve given on Fig. II-29. The final result is in curve form on Fig. II-30 and this curve shows the distance to frequency relation necessary to meet the specified limits. It will be noted that the frequencies in the range of 0.5 to 2 Mc/s require the greatest distance from the line. In this range atmospherics have often prevented radio noise measurements on power lines. Because of this it may not be realistic to go to the greater distance because of line radio noise in heavy rain. The effect of atmospherics on siting distance should therefore be considered for the siting location.

3.2 Siting Distances from Line with Gap-Type Source

The siting distances because of radio noise from a gap-type source on the line will be different than for conductor corona. The frequency spectra of a gap-type source is given on Fig. II-31. A sample limit curve is also shown. From the difference in dB between these two curves and the lateral attenuation curves Fig. II-6 to II-25, it is possible to obtain the siting distance curve with frequency for this gap-type source. The resulting curve for this example is shown on Fig. II-30.

3.3 Example - Comparison of Lines with Conductor Corona

For comparison of two lines with radio noise due to conductor corona equations 3, 4 and 5 and curves of Fig. II-28 and Fig. II-29 are used. This comparison is intended at the basic lateral distance of 200 feet. The correction for line conductor height h, for this distance is taken as:

$$db = 20 \log_{10} \frac{h_2}{h_1} \qquad (6)$$

which is a good approximation for the distance of 200feet. Receiver antenna heights are assumed to be the same for both cases.

The parameters and radio noise corrections for the example lines are as follows:

	Line No. 1	Line No. 2
Phase Conductor Configuration	Horizontal	Horizontal
Phase Conductor	Bundle of 2 -1.0" diam. -18"	Single 1.6" diam.
Phase Spacing	28 ft.	26 ft.
Line Voltage	345 kV	345 kV
Conductor Height h	50 ft.	40 ft.
Altitude	1000 ft.	5000 ft.
*Relative Air Density δ	0.9710	0.8616

*Taken from NACA Std. Atmosphere Tables & Data (Ref. NACA Tech. Report 218)

	Line No. 1	Line No. 2
Center Phase Gradient Factor From Fig. II-33	0.052	0.0485
Center Phase Gradient in kV_{rms}/cm, 345 x grad. factor	17.93	16.73
Outside Phase Gradient Factor From Fig. II-32	0.0485	0.046
Outside Phase Gradient in kV_{rms}/cm	16.73	15.86
Gradient Correction (Center Ph.) From eq. 4 or Fig. II-28	0 dB	-4.2 dB
Diameter Corr. From eq. 3 or Fig. II-28	0 dB	+6.1 dB
Altitude Corr. From eq. 5, Approx. From Fig. II-28	+0.88 dB	+4.6 dB
Net Difference for Altitude	0	+3.72 dB
Corr. For Cond. Height, From eq. 6		-2.0 dB

Difference in Field Strength at 200 Feet = -4.2 + 6.1 + 3.72 - 2
= +3.62 dB

The result from this method of comparison is that line No. 2 will give 3.62 dB more radio noise at 200 feet from center of line than line No. 1 for the same conductor surface condition in fair weather. If the gradients of the outside phase conductors are used the difference is 4.78 dB.

The value of 4.78 dB is added to the curves for 50 feet in Fig. II-29 to obtain radio noise spectrum for line No. 2. From this spectrum the siting distances can be found as was done in Sections 2.2.3 and 3.1.

For single circuit vertical configuration lines radio noise due to conductor corona will be determined principally by the gradient and height of the center phase conductor. When comparing single circuit vertical configuration lines the center phase conductor gradient can be obtained to sufficient accuracy from Fig. II-33, as was done for the horizontal configuration line example. For double circuit lines of various configurations the effect of conductor phasing on the conductor gradients may have to be considered, especially if the arrangement appears to increase the gradient of the higher conductors. For balanced double-circuit vertical configuration the gradient can be obtained to sufficient accuracy for radio noise prediction from Figures II-32 and II-33.

All corrections for receiver antenna height and lateral attenuation with frequency and ground conductivity are the same as for low voltage lines. These factors have been discussed in Section 2 above.

4. Recommendations

4.1 For critical communication areas it is recommended that vehicles with adequate instrumentation, including directional antennas, be available for quickly locating a radio noise generator which is causing radio interference. See reference 35, Part II in Vol. III.

4.2 The site should be protected from its own power supply line. Underground cable wrapped with high permeability tape can be used between overhead lines and the site. In this way the site can be isolated from radiating lines and the cable will attenuate conducted radio noise.

4.3 In some cases the field strength actually decreases faster than $\frac{1}{d}$. It may, however, be difficult to accurately account for terrain conductivity without actual measurements. If no measurements are available it is recommended that calculations be based on good conductivity earth so as to be on the conservative side.

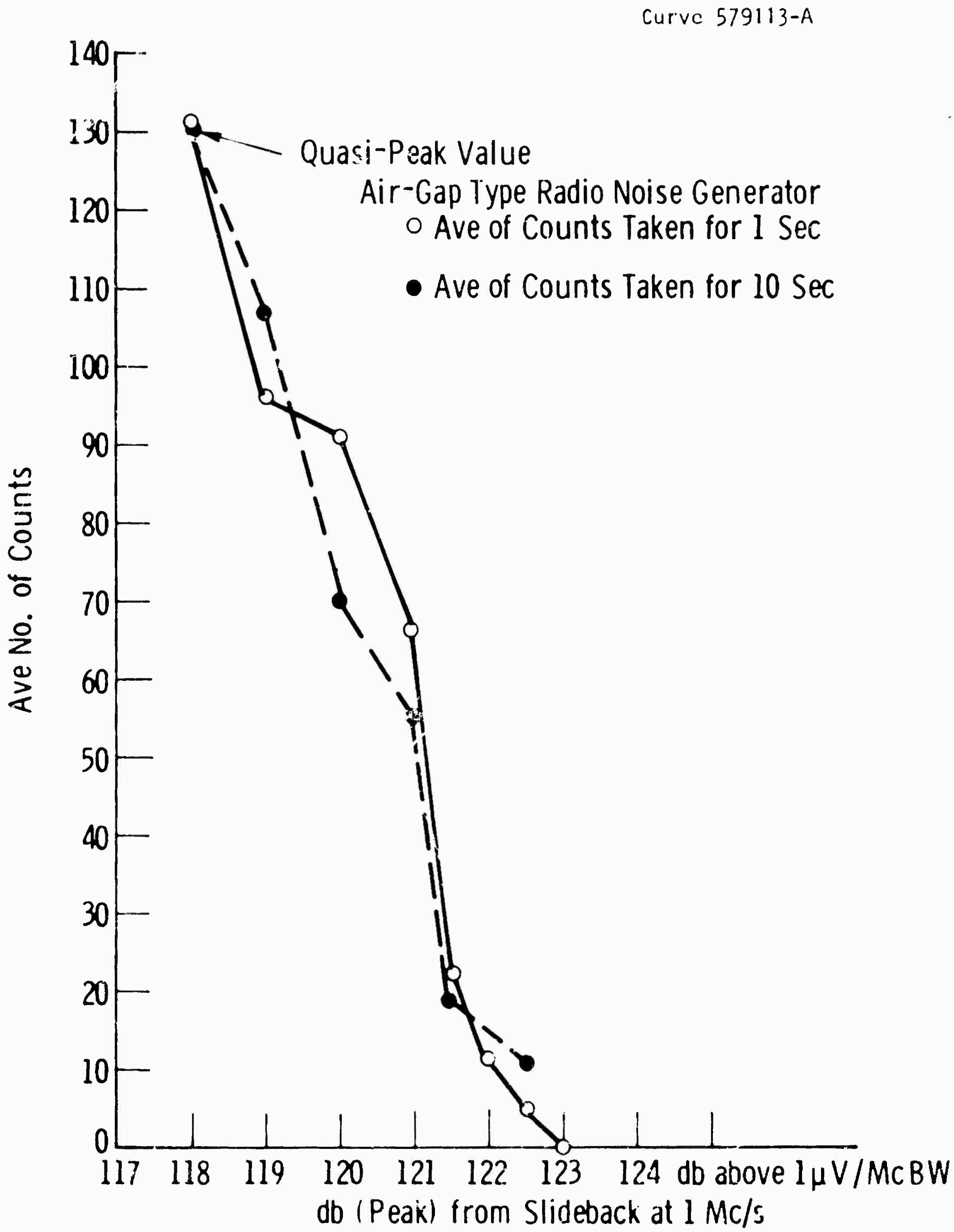

Fig. II-1—Variation of peak value with number of pulses per seconds

Curve 579600-A

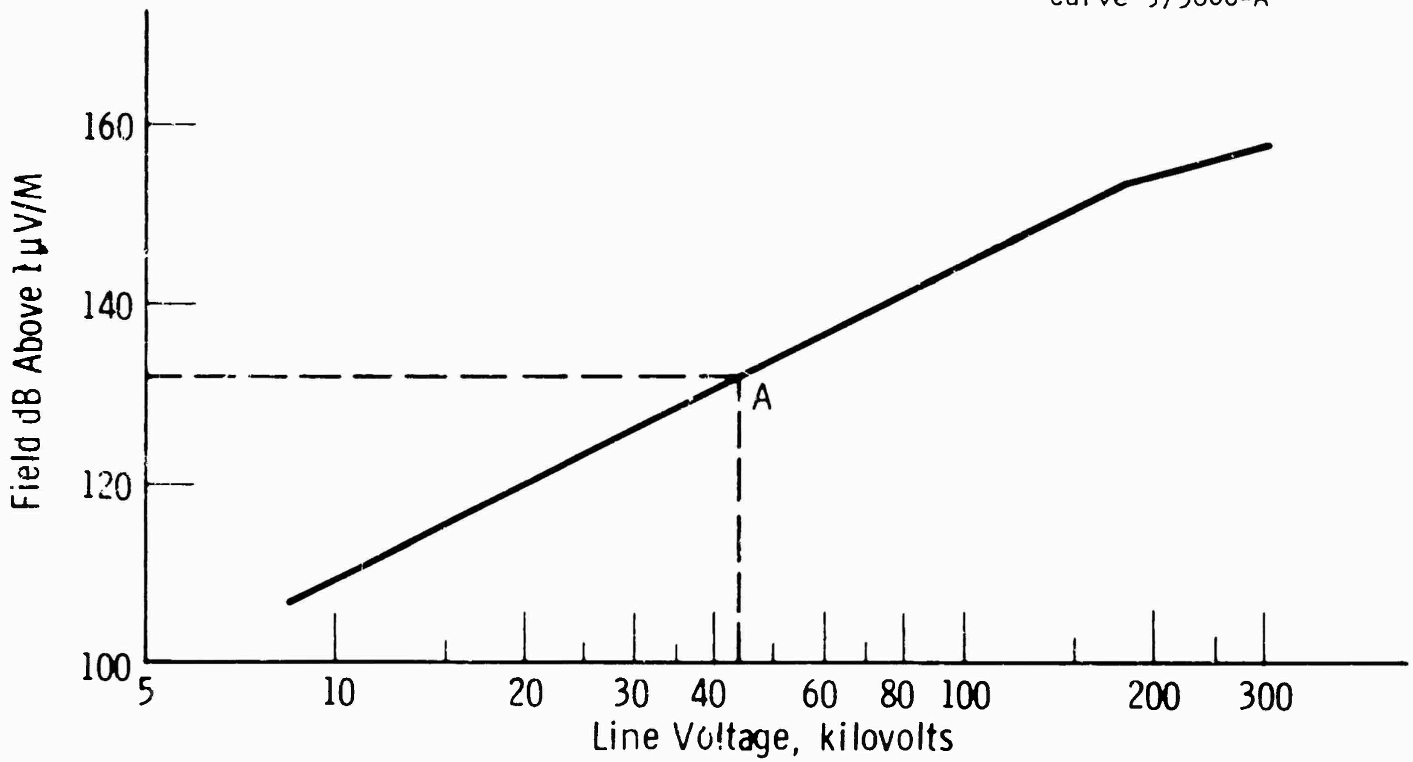

Fig. II-2 —60 cycle electric field 200 feet from ℄

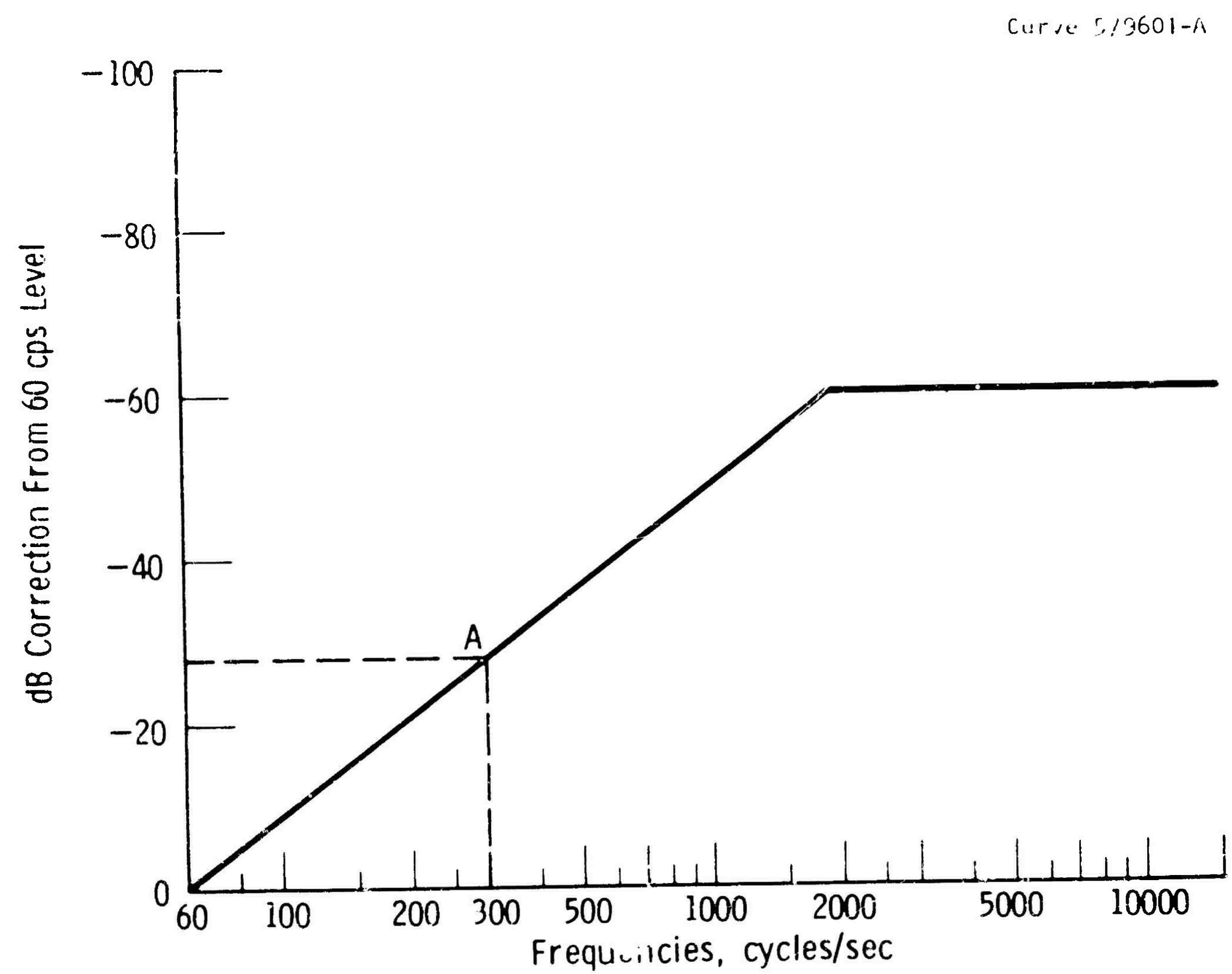

Fig. II-3—Correction of 60 cycle harmonics from 60 cycle level

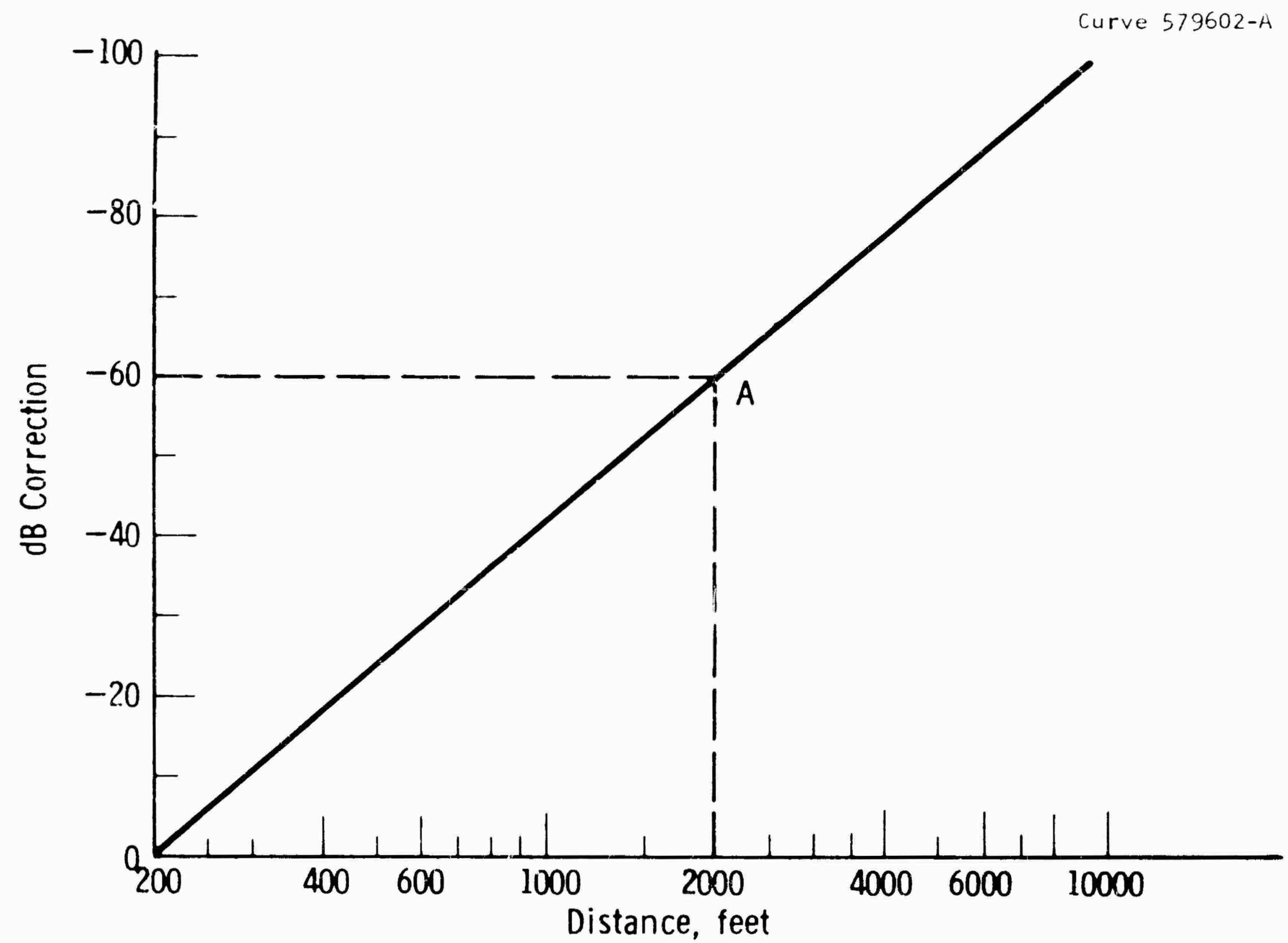

Fig. II-4—Distance correction for low frequencies (60 cps to 15 kc/s)

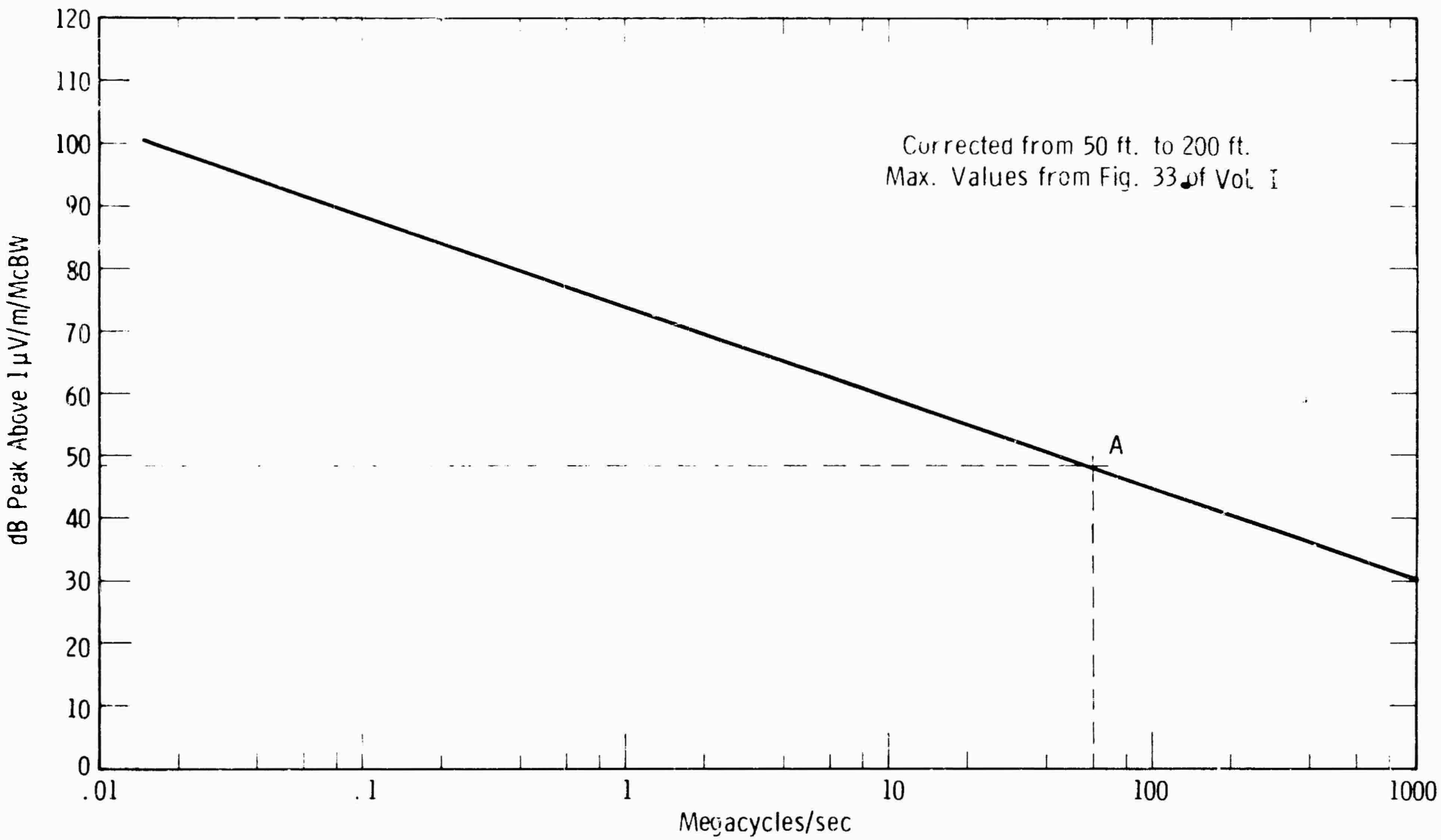

Fig. II-5—Frequency spectrum for low voltage line prediction based on max. measured values

Curve 579281-A

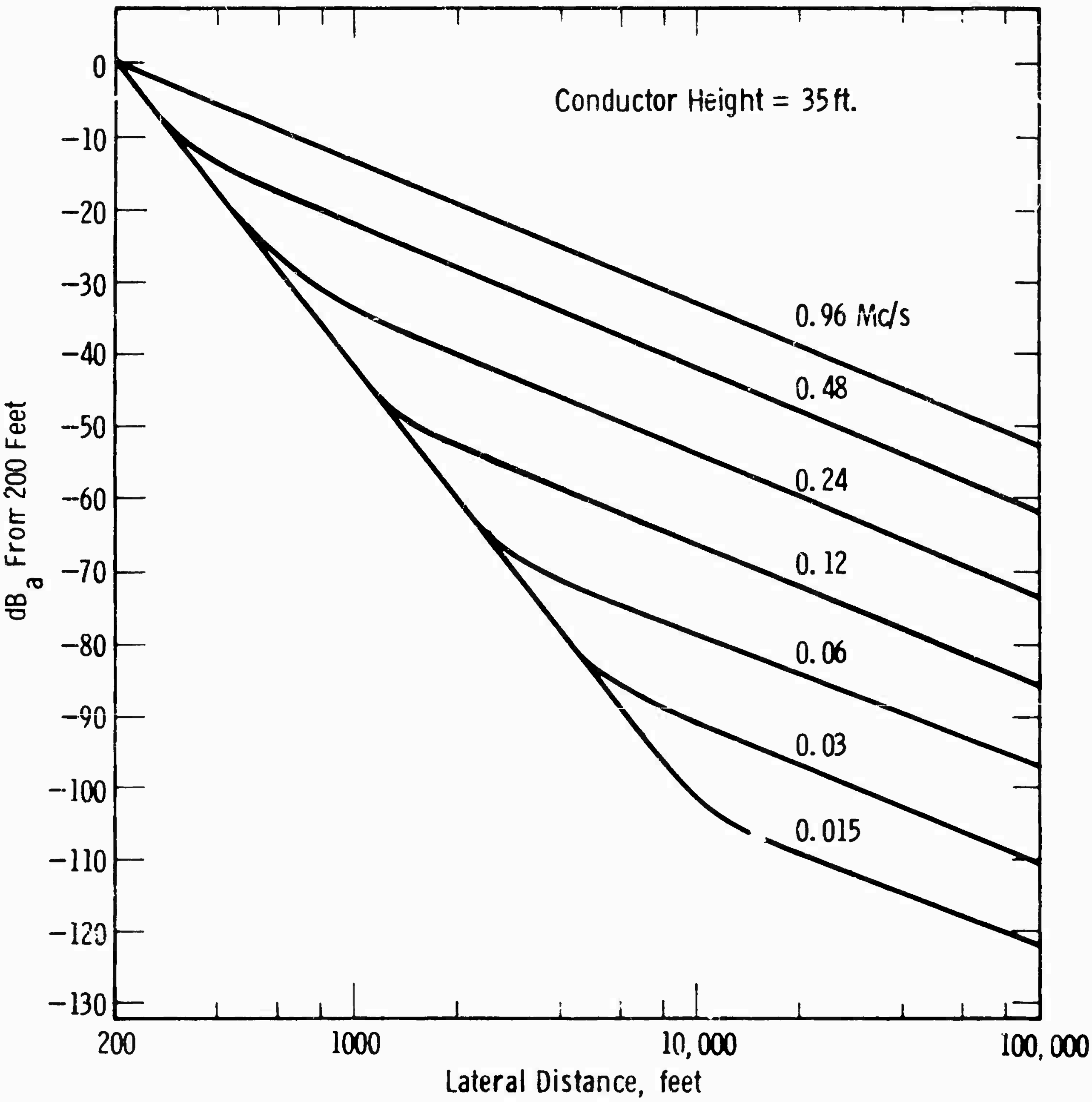

Fig. II-6—Lateral attenuation 0.015 - 0.96 Mc for 35 foot conductor height (Calc.)

Curve 579282-A

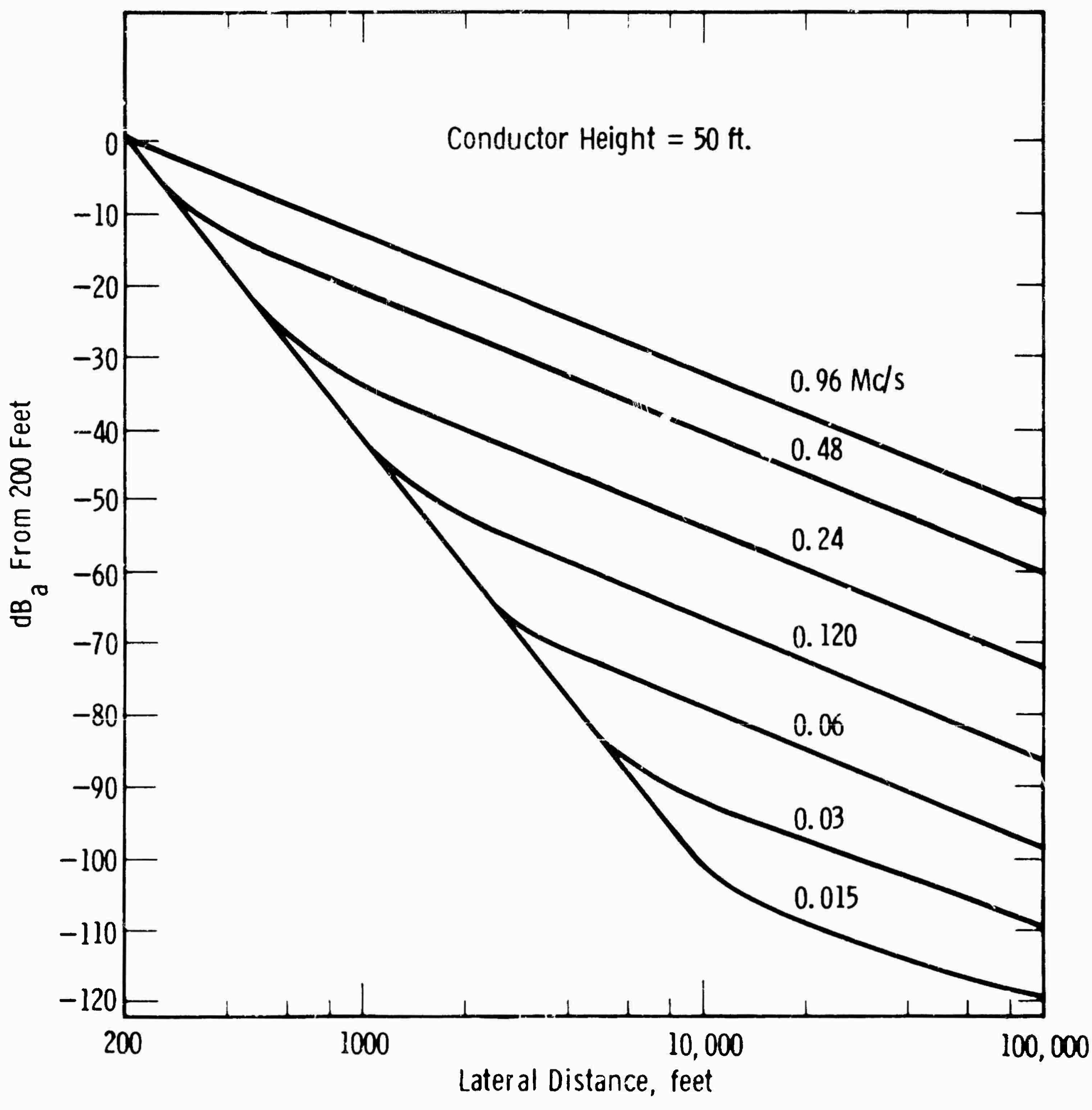

Fig. II-7 —Lateral attenuation 0.015-0.96 Mc/s for 50 foot conductor height (Calc.)

Curve 579283-A

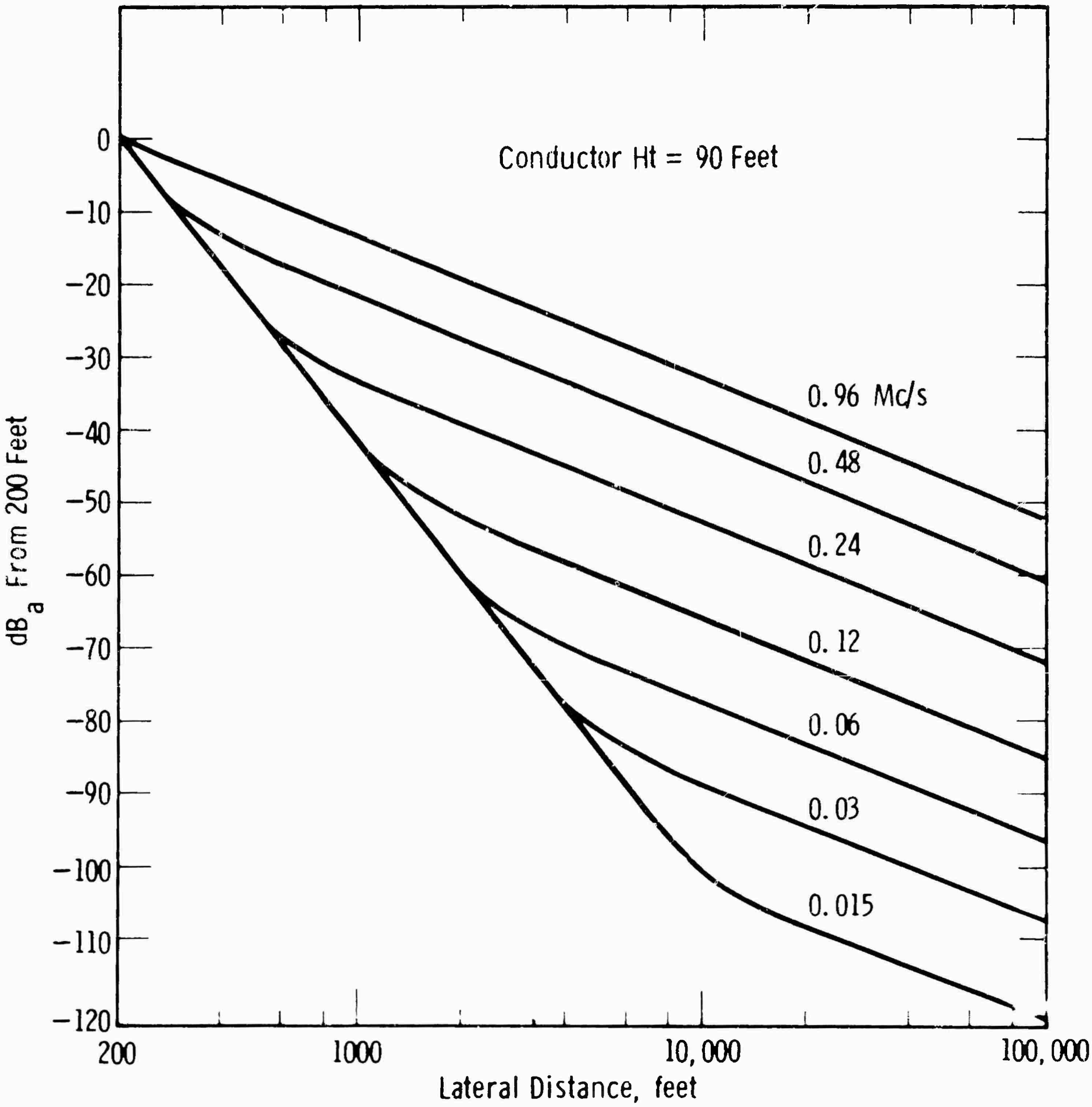

Fig. II-3 — Lateral attenuation 0.015-0.96 Mc for 90 foot conductor height (Calc.)

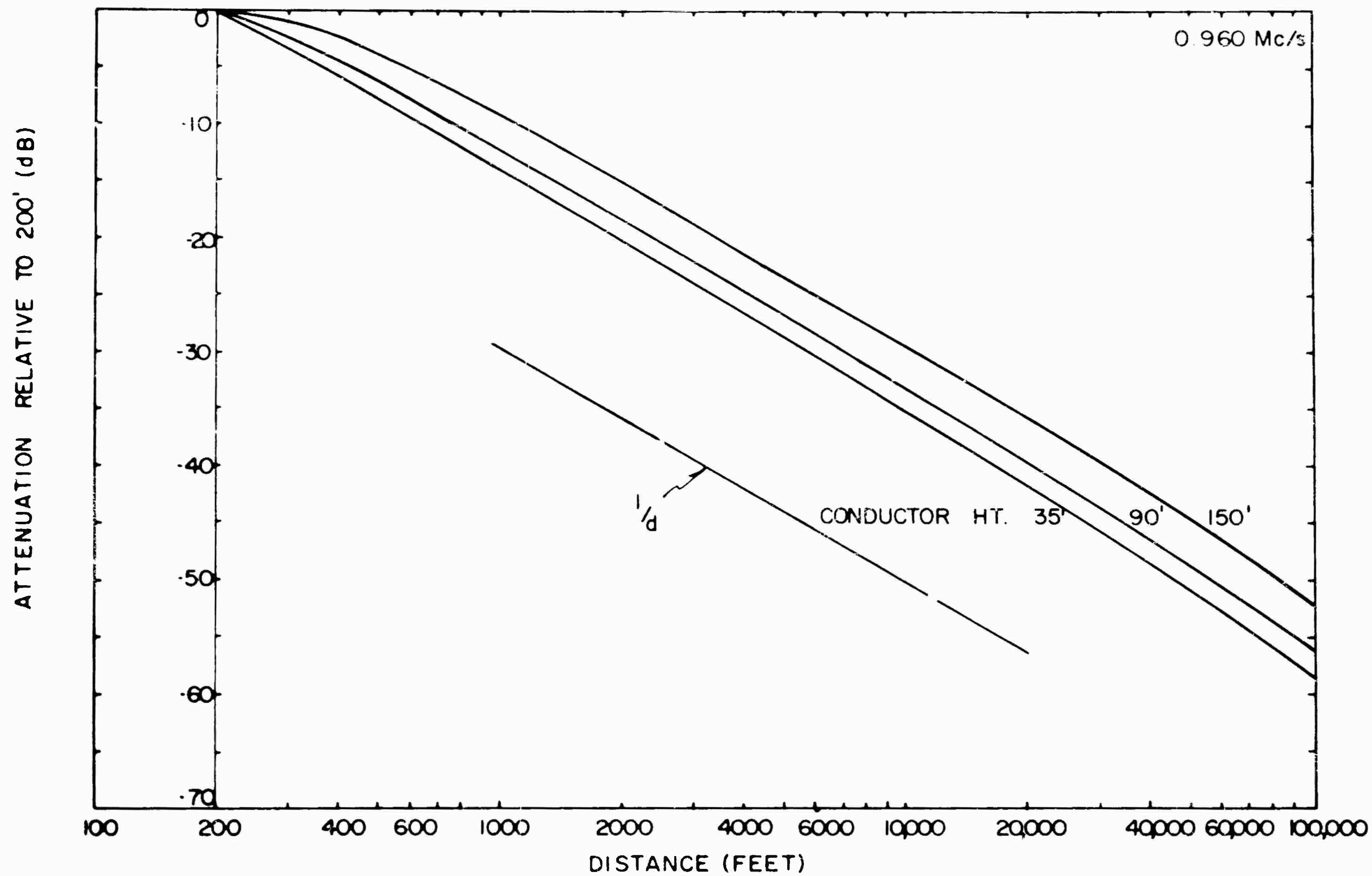

Fig. II-9-ATTENUATION OF FIELD WITH DISTANCE FOR 3 FT. VERTICAL ANTENNA AT 0.960 Mc/s

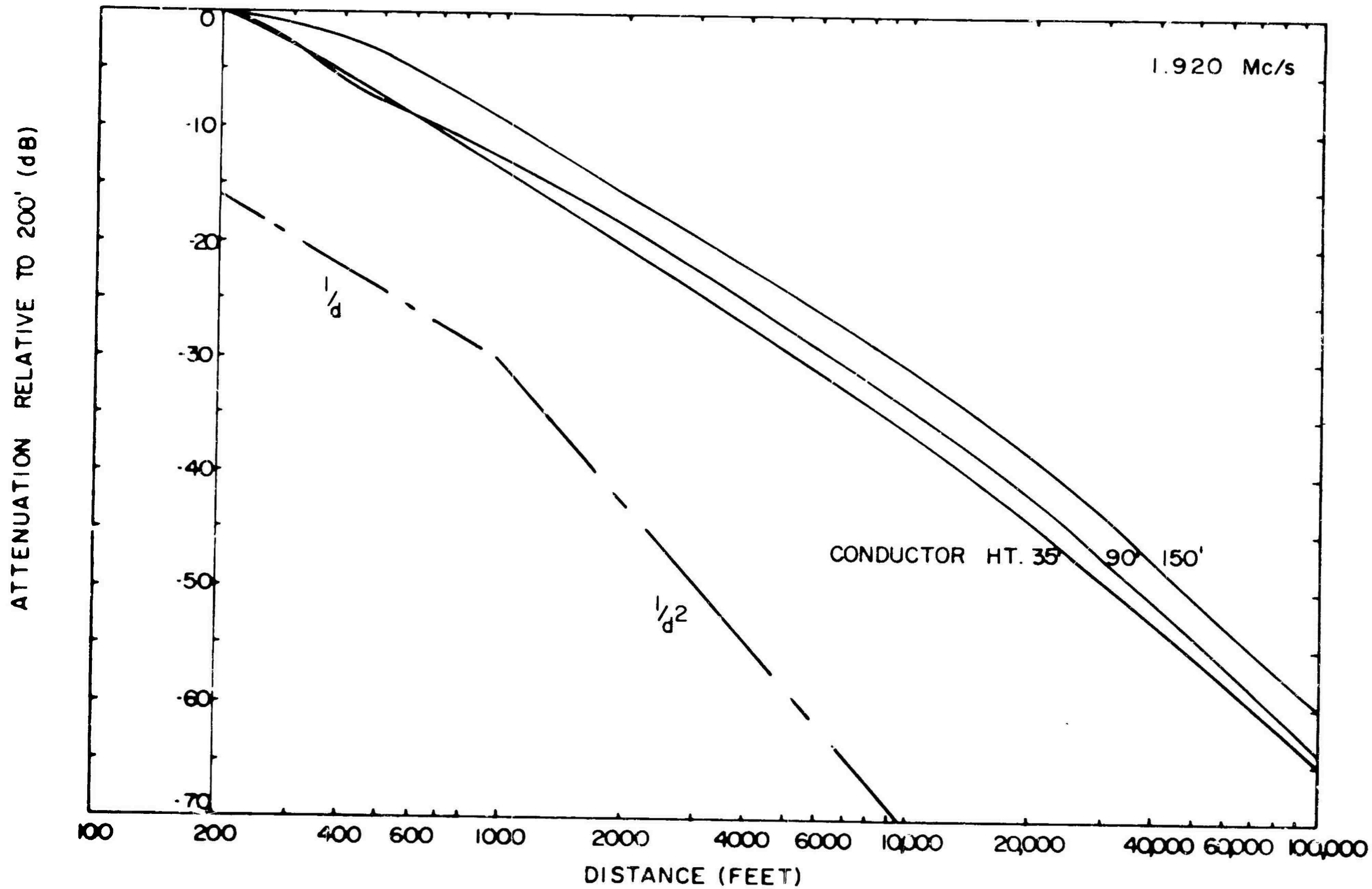

Fig.II-10–ATTENUATION OF FIELD WITH DISTANCE FOR 3 FT. VERTICAL ANTENNA AT 1.920 Mc/s

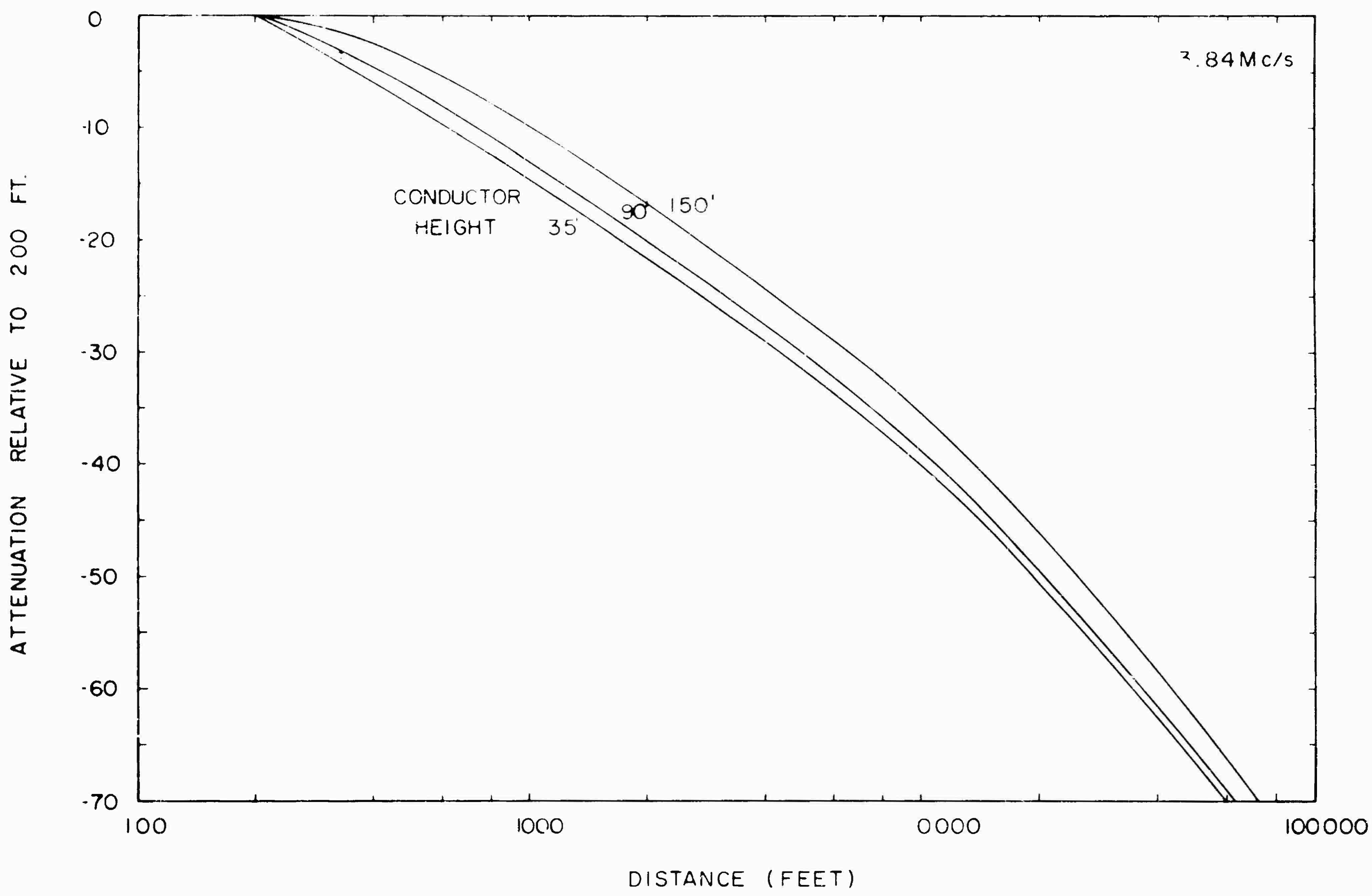

Fig. II-11-ATTENUATION OF FIELD WITH DISTANCE FOR VERTICAL ANTENNA 3.84 Mc/s

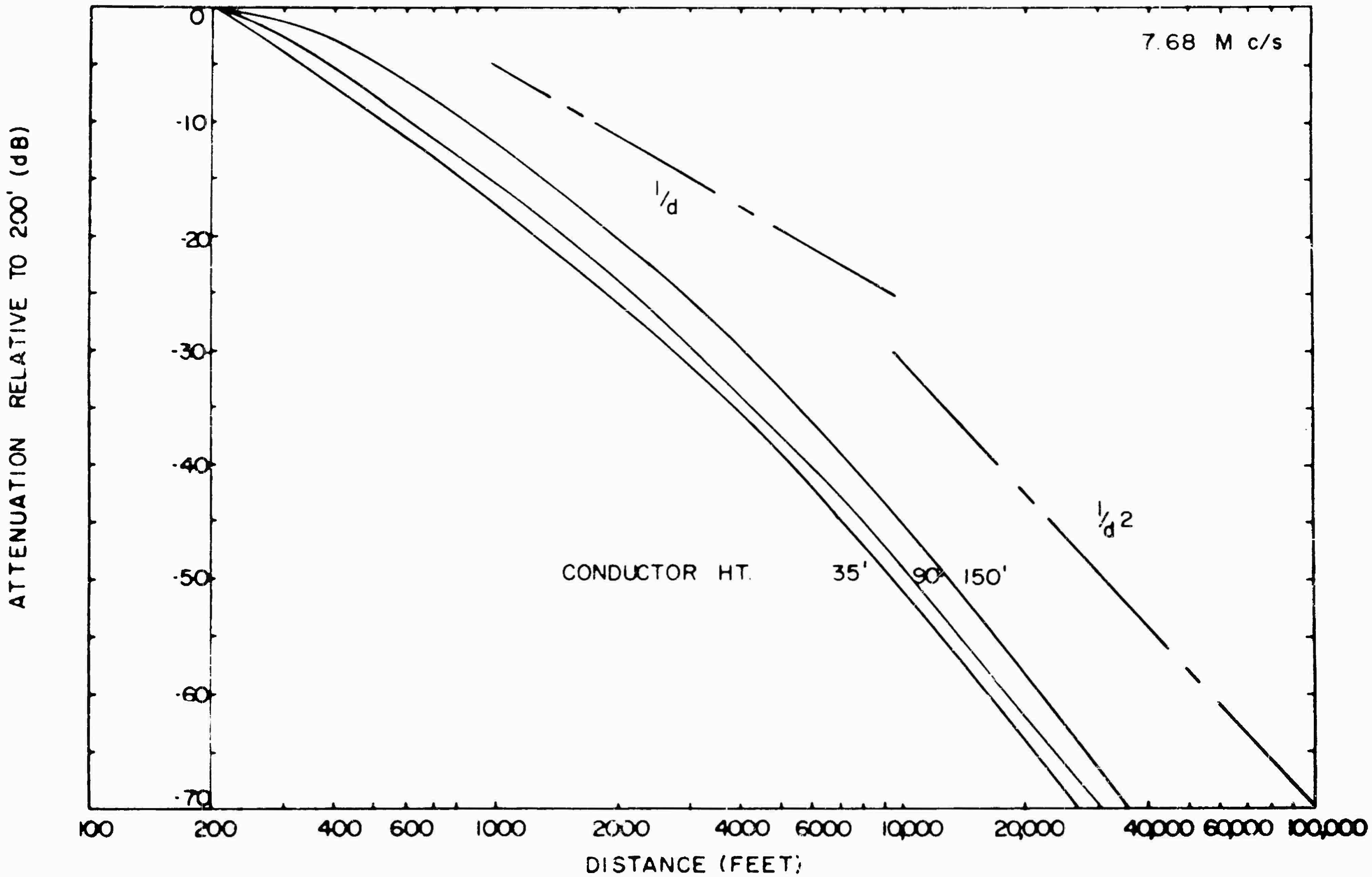

Fig. II-12 - ATTENUATION OF FIELD WITH DISTANCE FOR 3 FT VERTICAL ANTENNA AT 7.68 M c/s

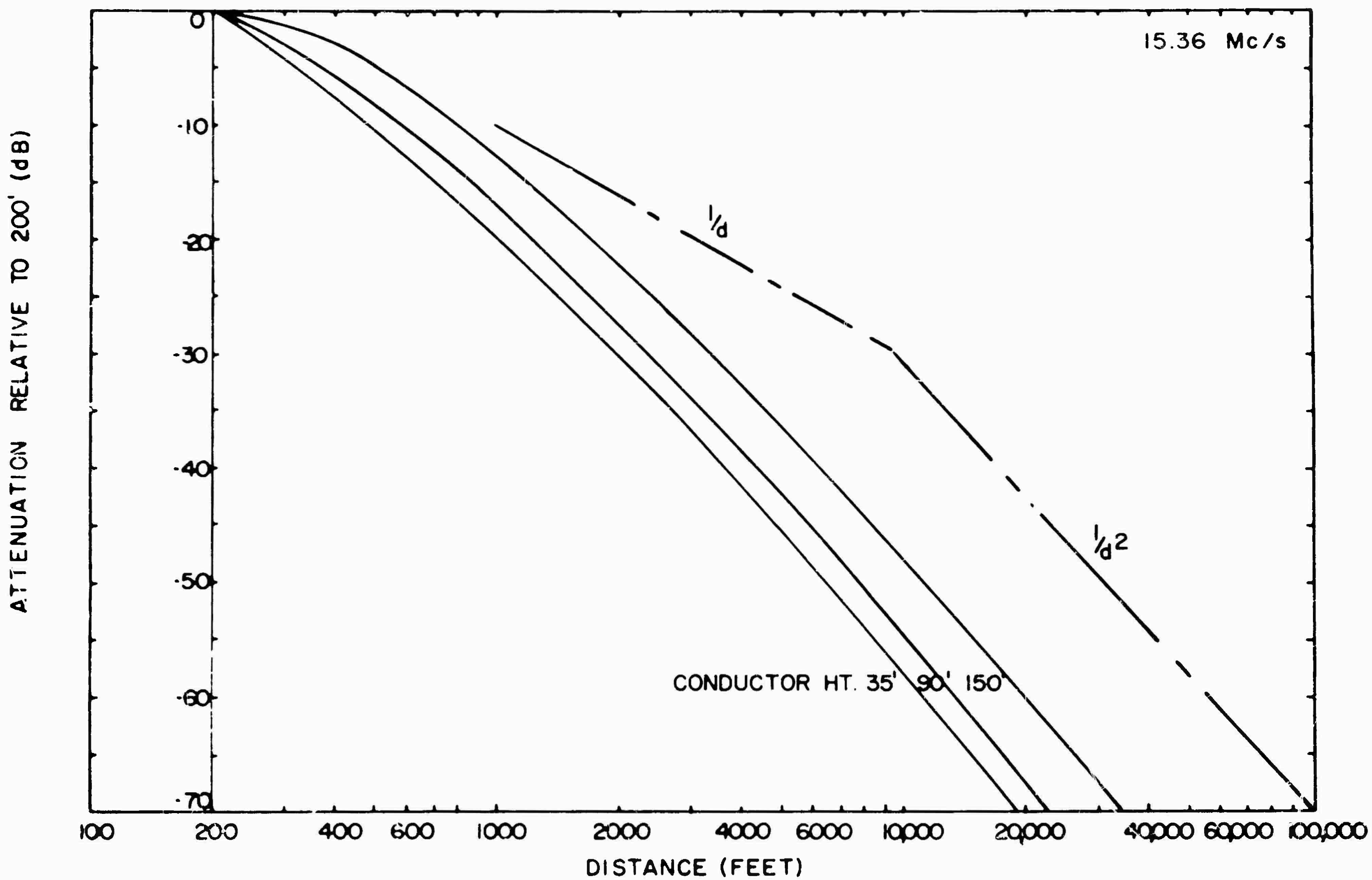

Fig. II-13 – ATTENUATION OF FIELD WITH DISTANCE FOR 3 FT. VERTICAL ANTENNA AT 15.36 Mc/s

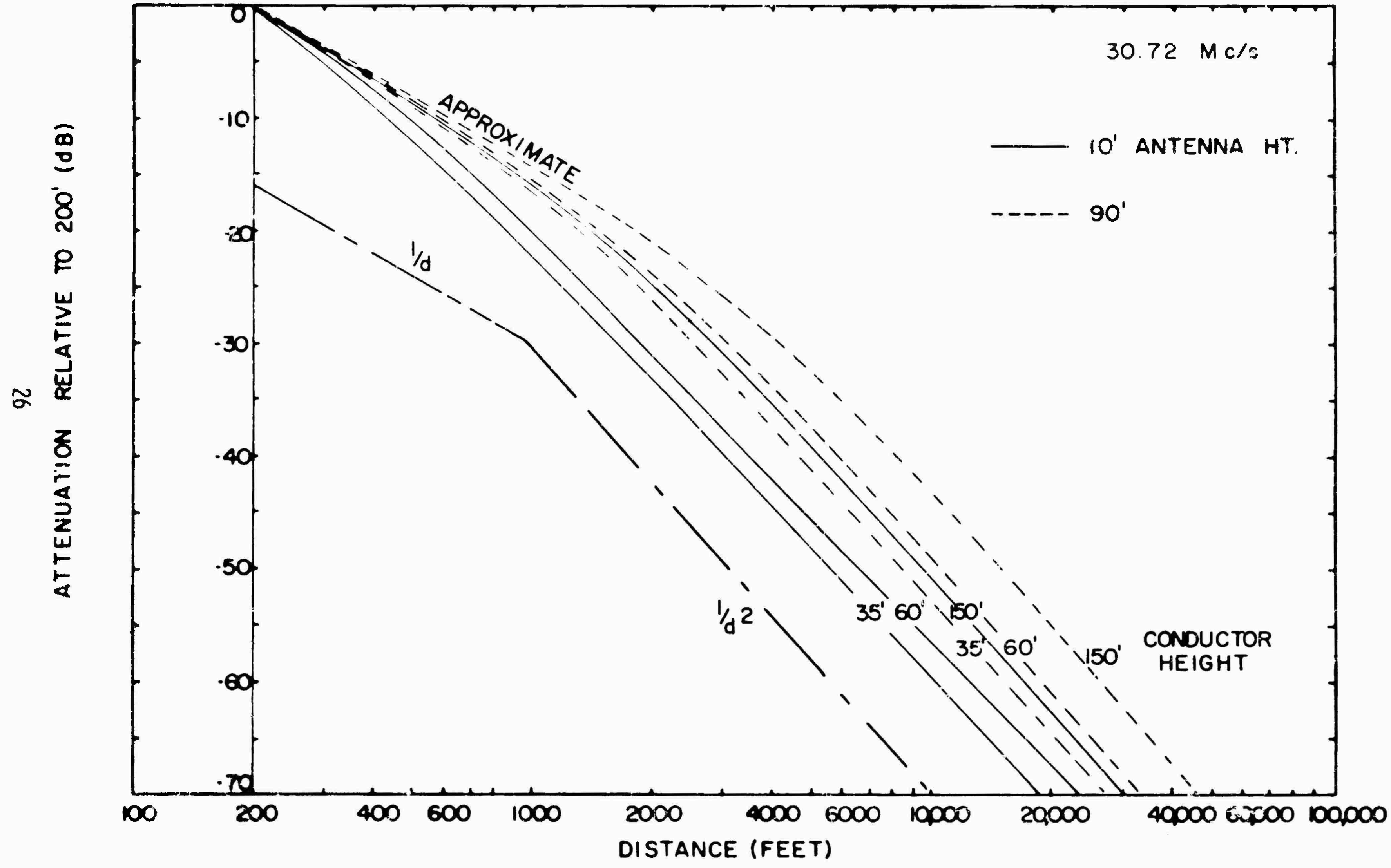

Fig.II-14—ATTENUATION OF FIELD WITH DISTANCE FOR VERTICAL DIPOLE AT 30.72 Mc/s

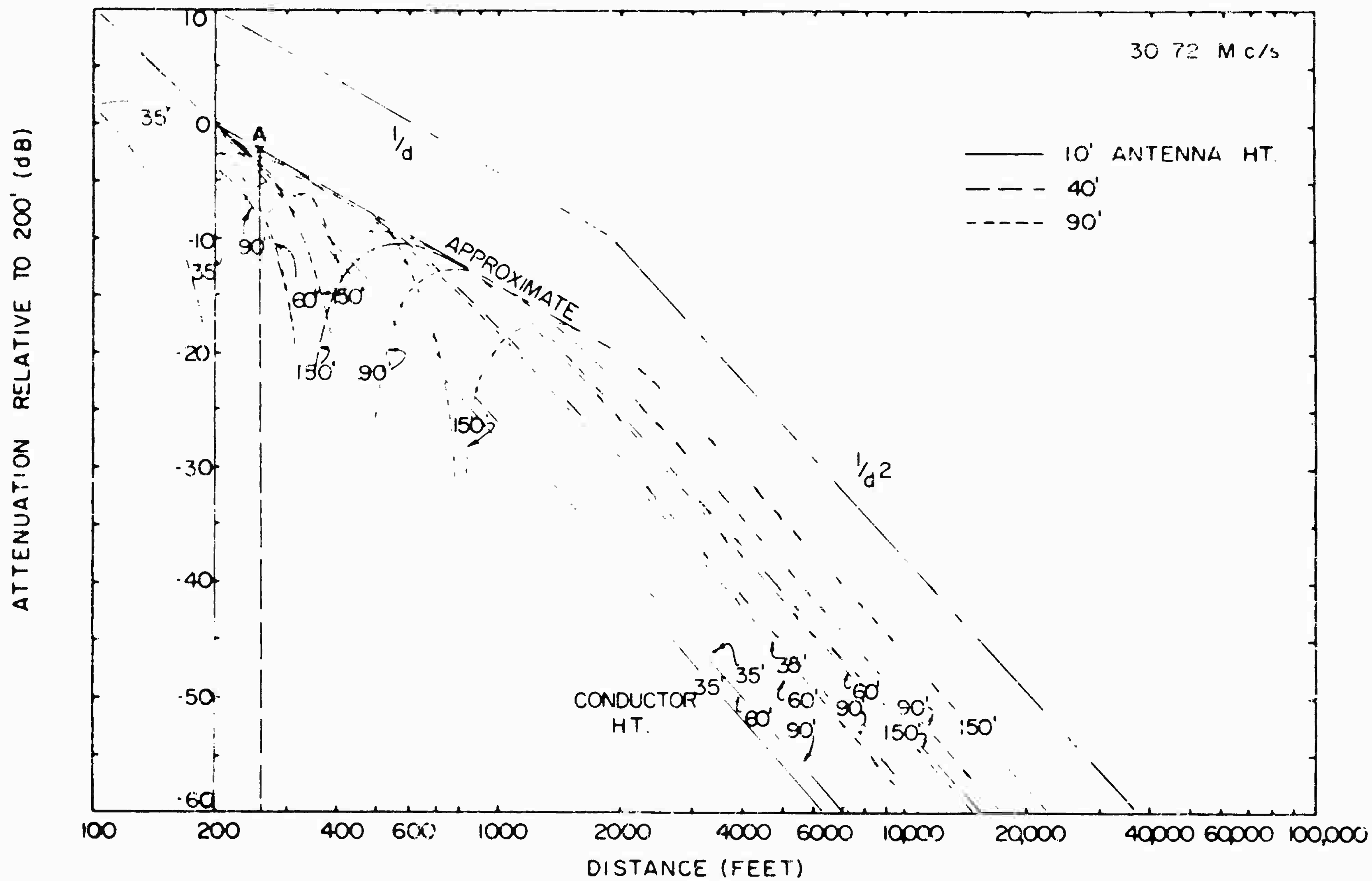

Fig.II-15-ATTENUATION OF FIELD WITH HORIZONTAL DIPOLE PERPENDICULAR TO LINE AT 30.72 Mc/s

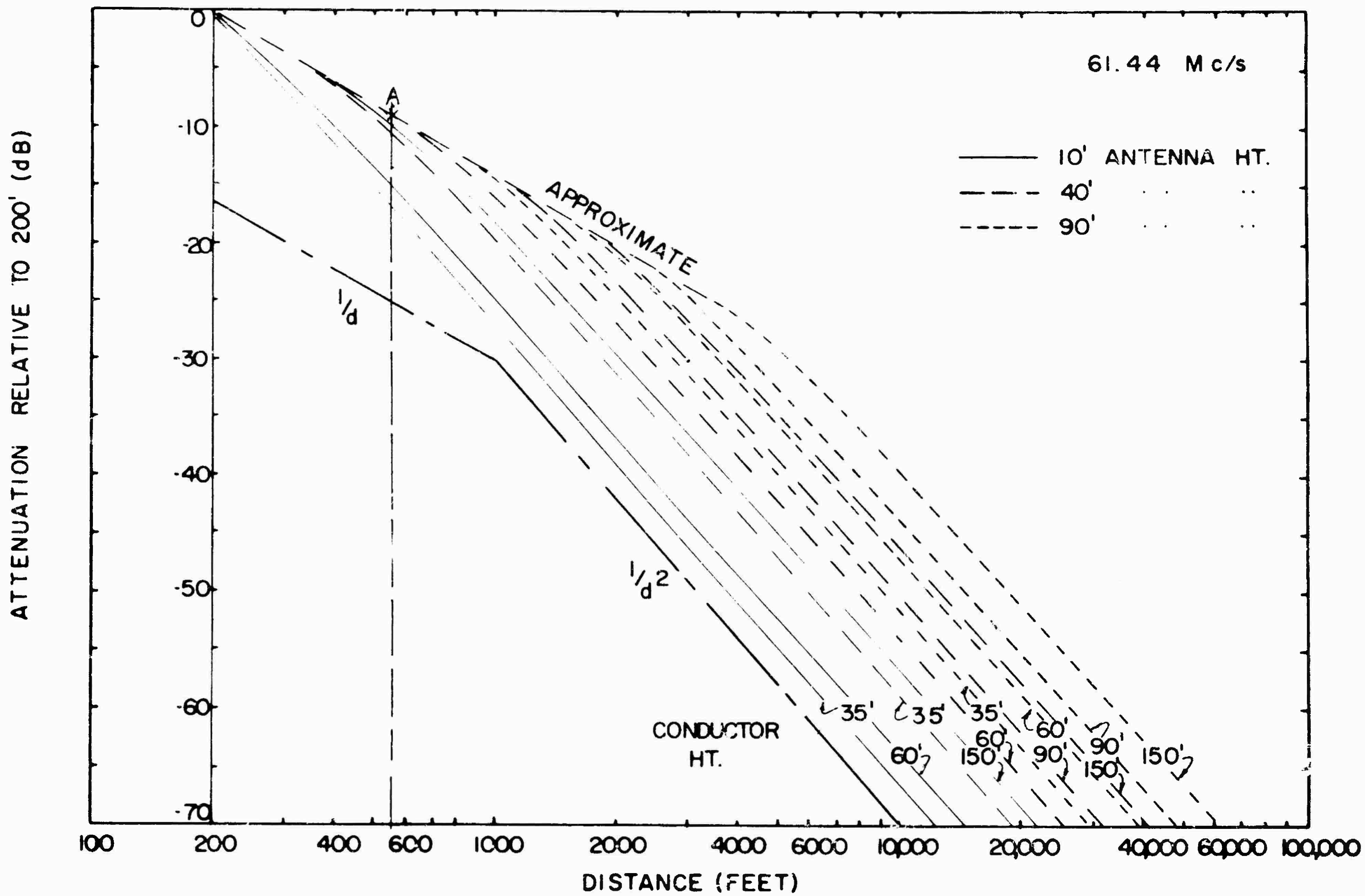

Fig.II-16 - ATTENUATION OF FIELD WITH DISTANCE FOR HORIZONTAL DIPOLE PERPENDICULAR TO LINE AT 61.44 Mc/s

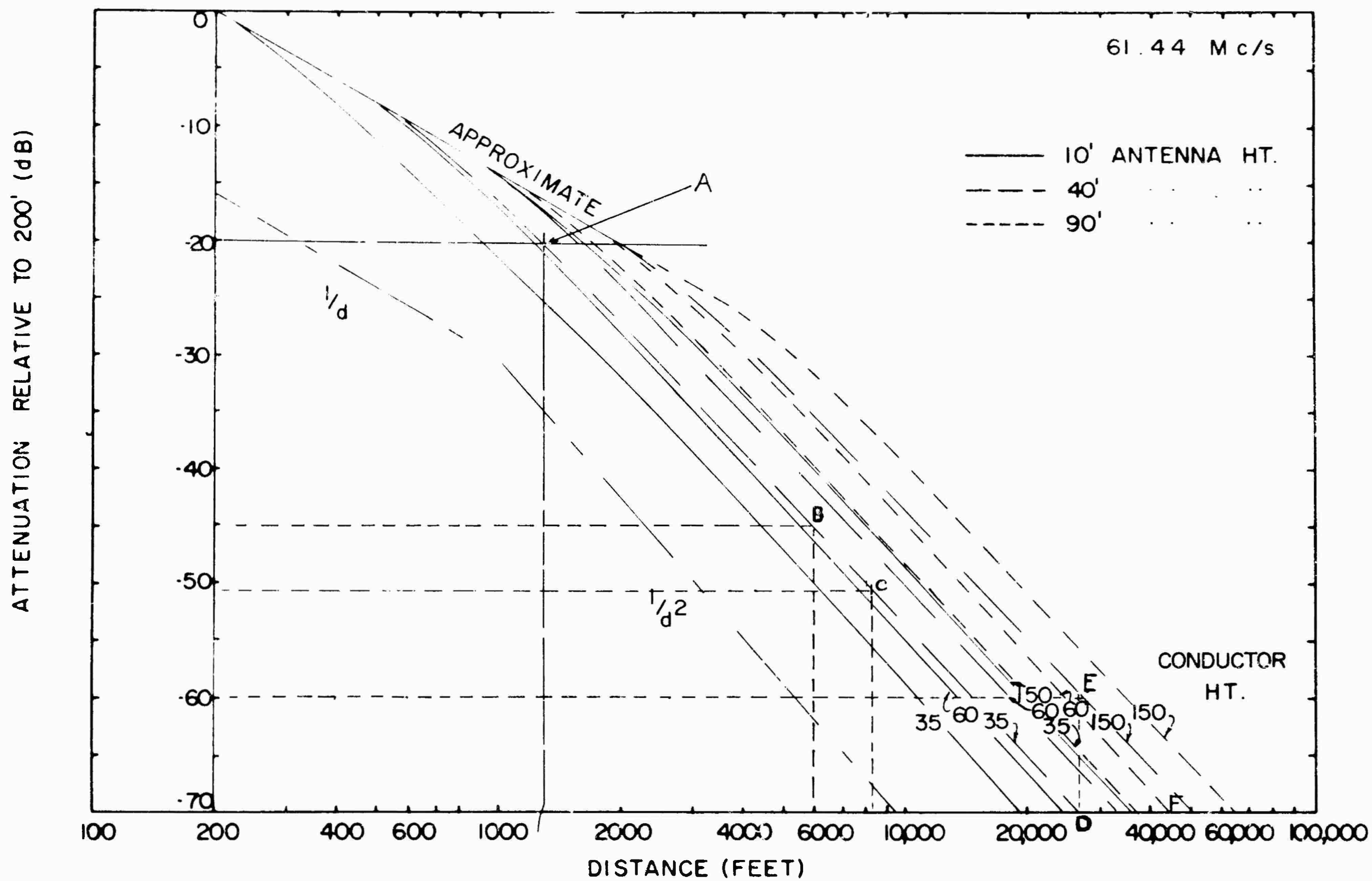

Fig.II-17-ATTENUATION OF FIELD WITH DISTANCE FOR VERTICAL DIPOLE AT 61.44 Mc/s

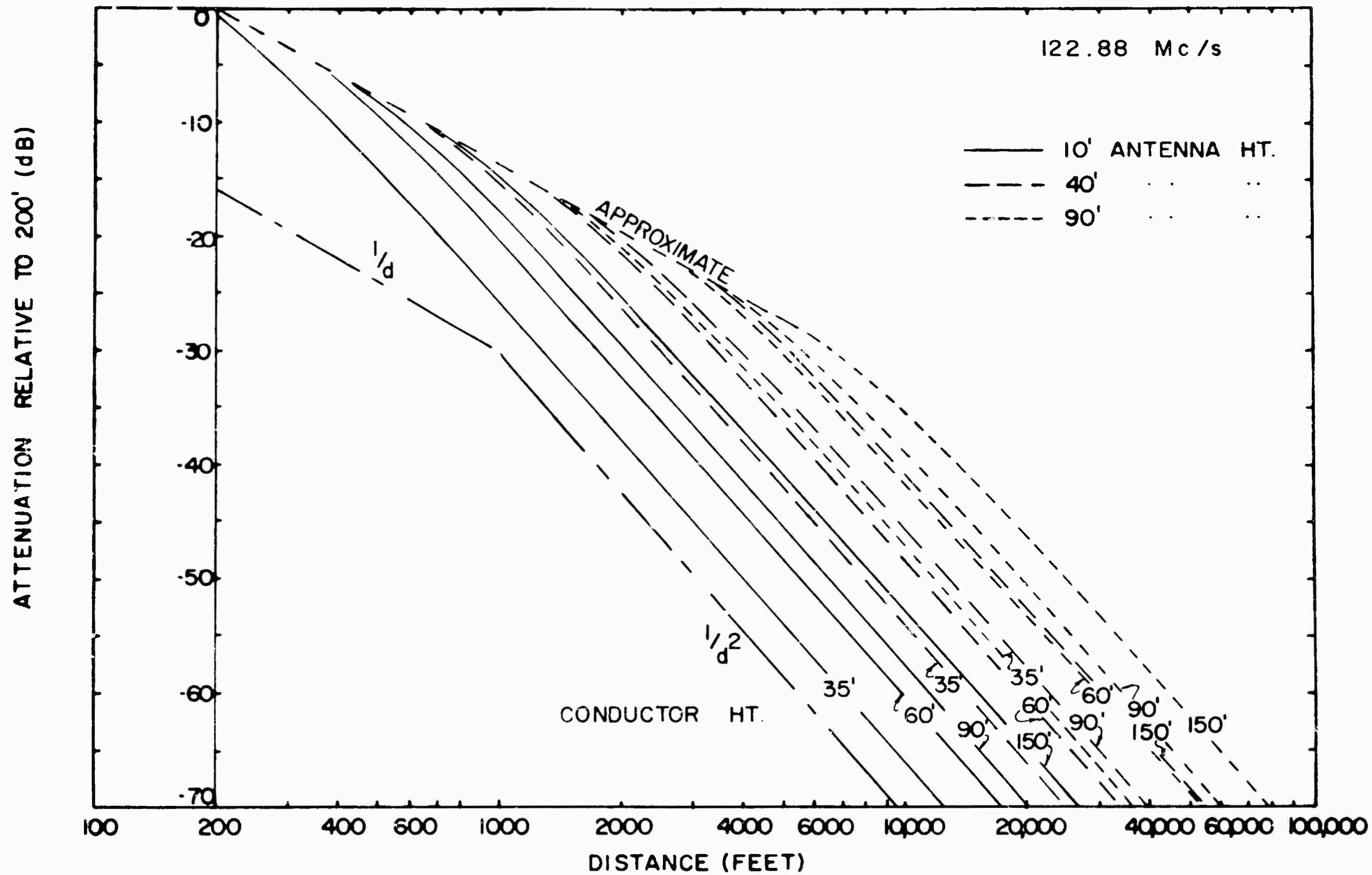

Fig. II-18-**ATTENUATION OF FIELD WITH** DISTANCE FOR HORIZONTAL DIPOLE AT 122.88 Mc/s

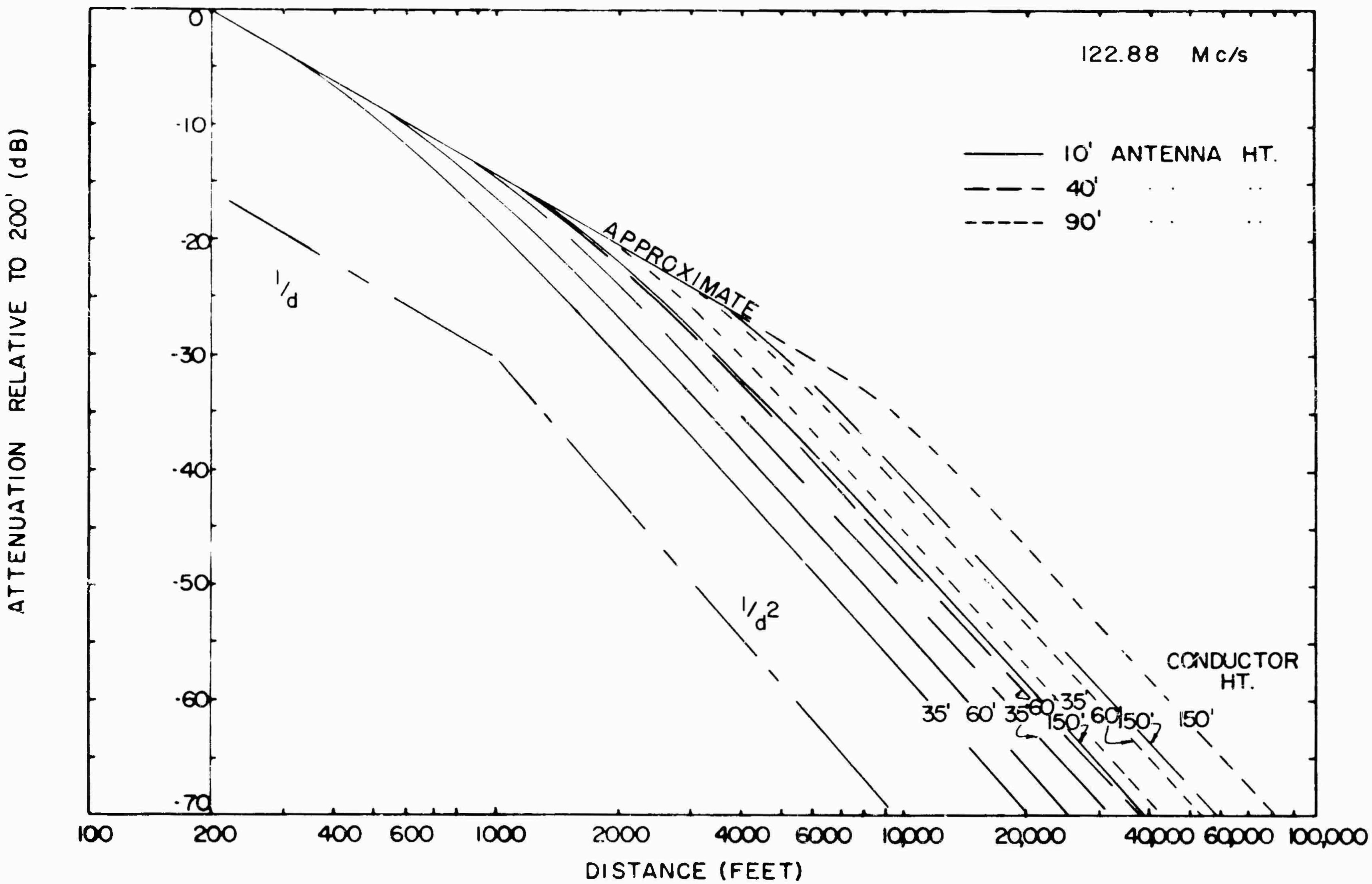

Fig.II-19-ATTENUATION OF FIELD WITH DISTANCE FOR VERTICAL DIPOLE AT 122.88 Mc/s

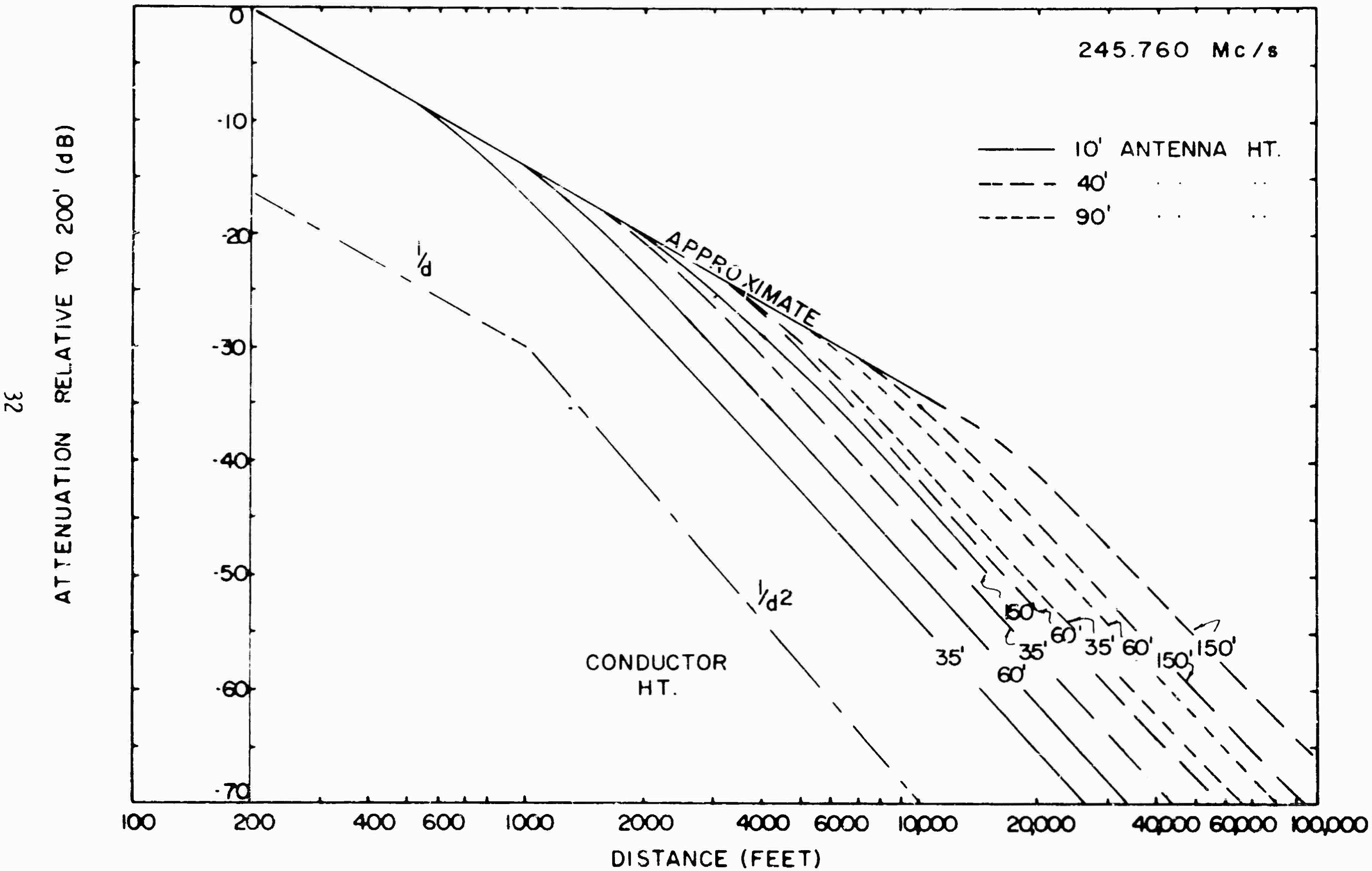

Fig.II-20-ATTENUATION OF FIELD WITH DISTANCE FOR VERTICAL DIPOLE AT 245.760 Mc/s

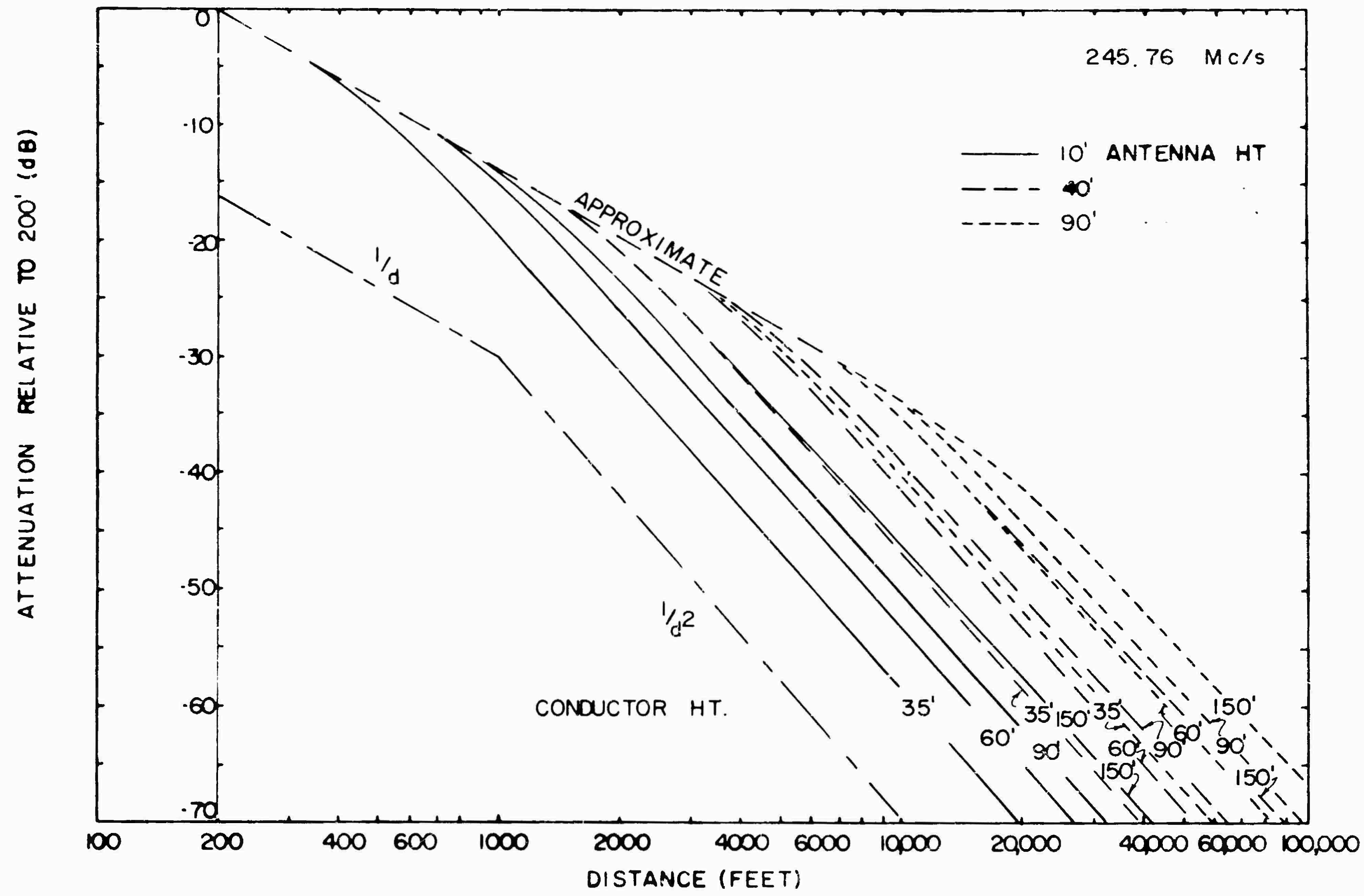

Fig.II-21 - ATTENUATION OF FIELD WITH DISTANCE FOR HORIZONTAL DIPOLE PERPENDICULAR TO LINE AT 245.76 Mc/s

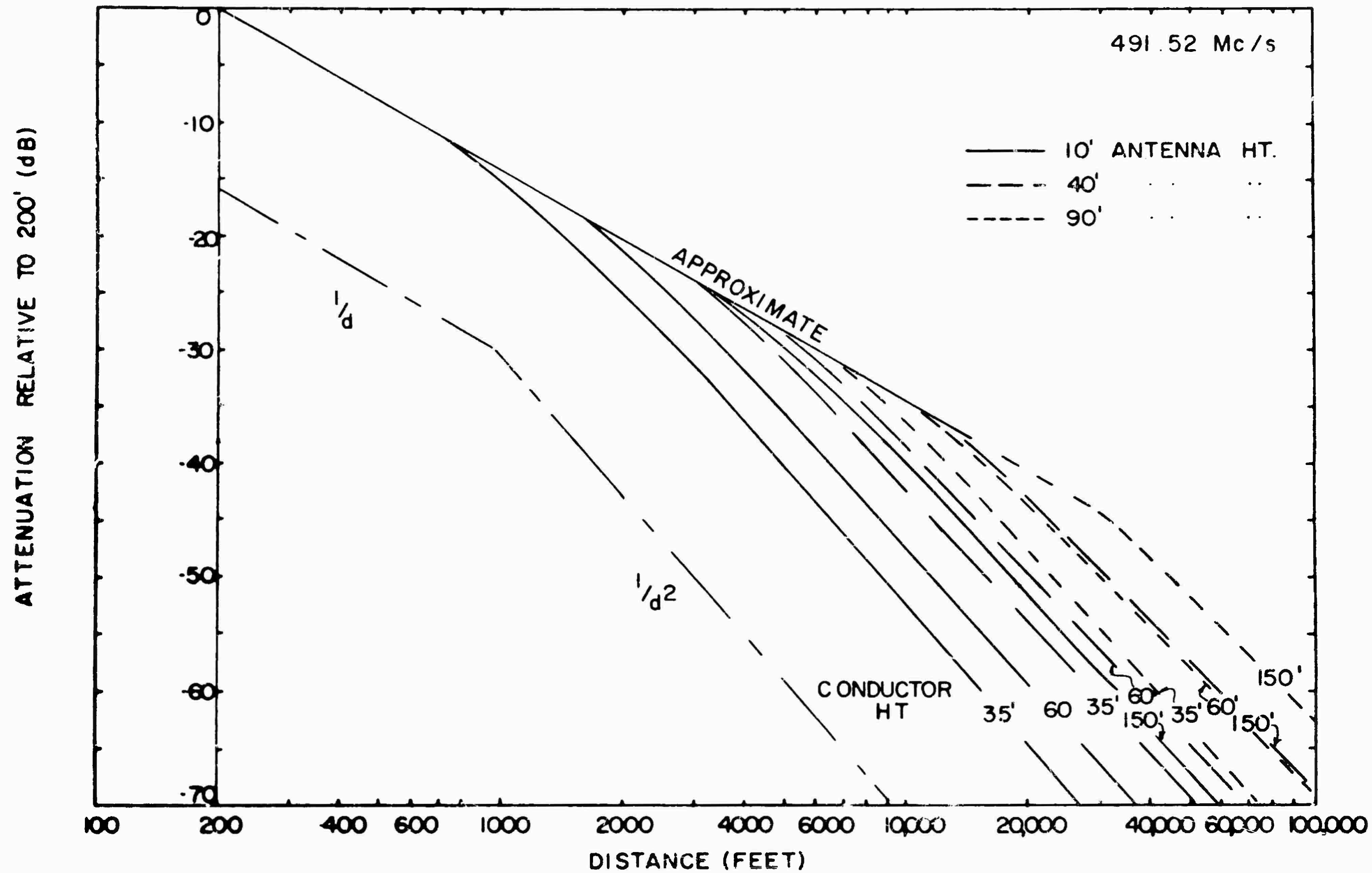

Fig.II-22 - ATTENUATION OF FIELD WITH DISTANCE FOR VERTICAL DIPOLE AT 491.52 Mc/s

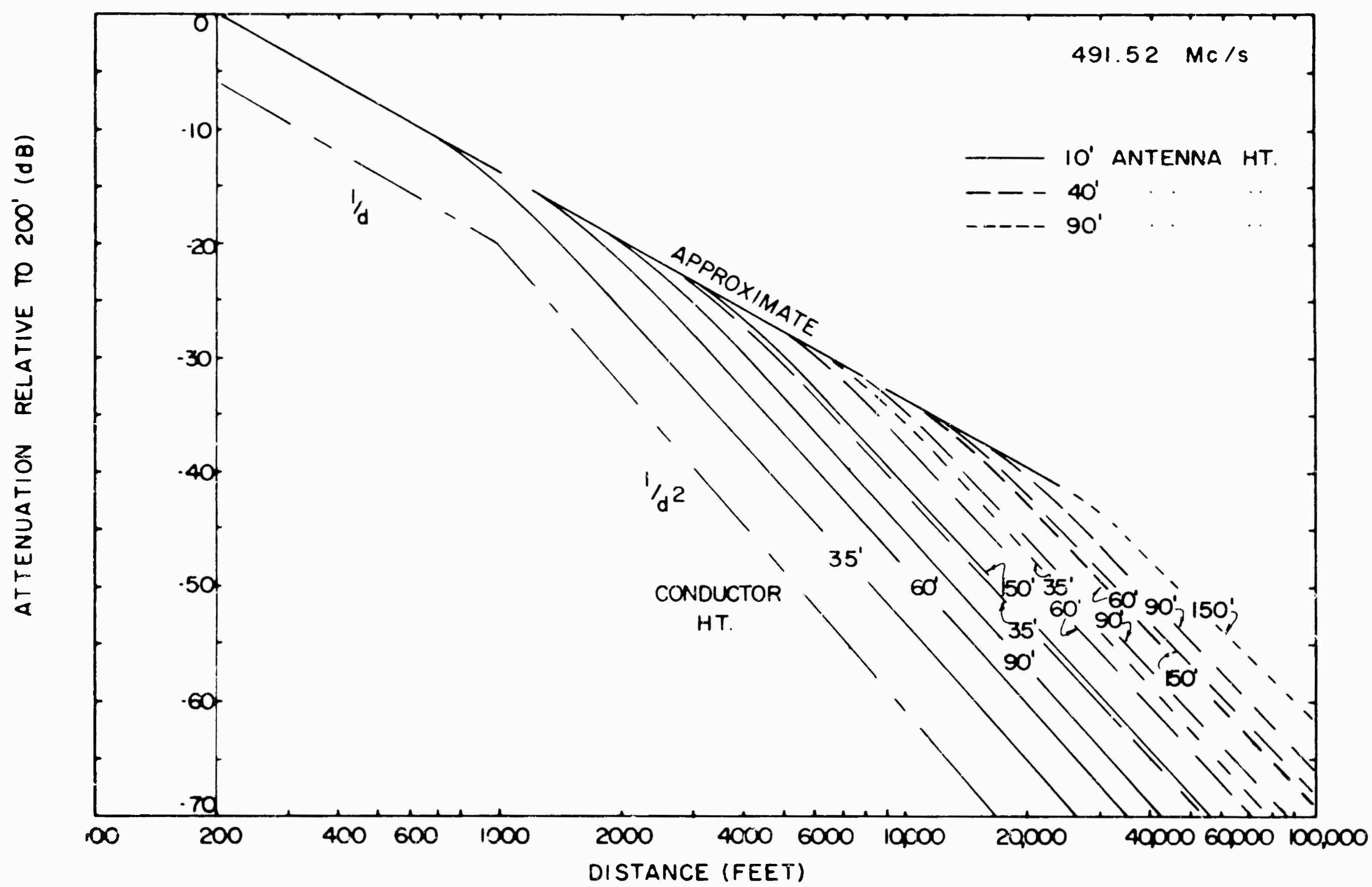

Fig.II-23-ATTENUATION OF FIELD WITH DISTANCE FOR HORIZONTAL DIPOLE PERPENDICULAR TO LINE AT 491.52 Mc/s

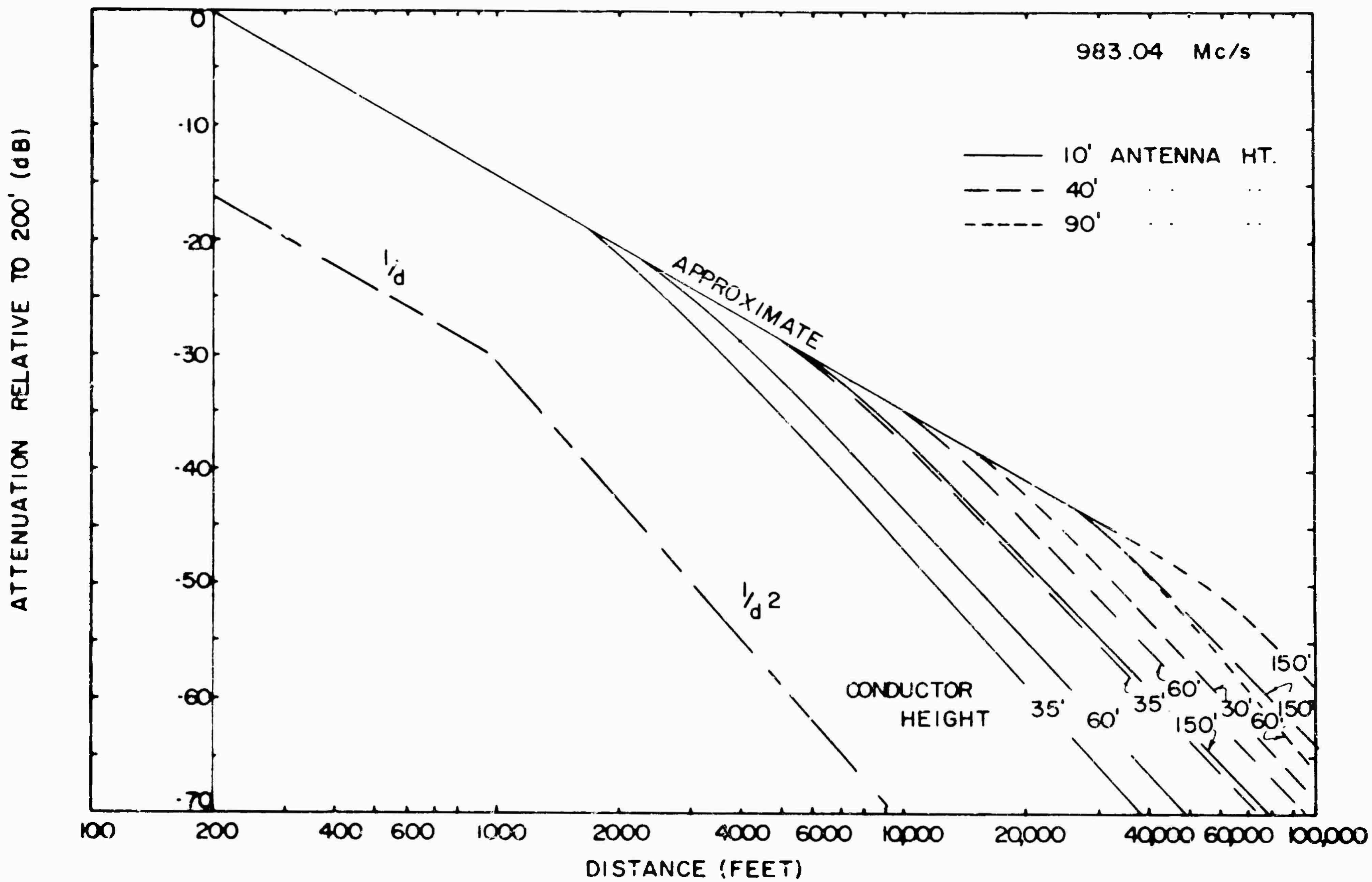

Fig. II-24 - ATTENUATION OF FIELD WITH DISTANCE FOR VERTICAL DIPOLE AT 983.04 Mc/s

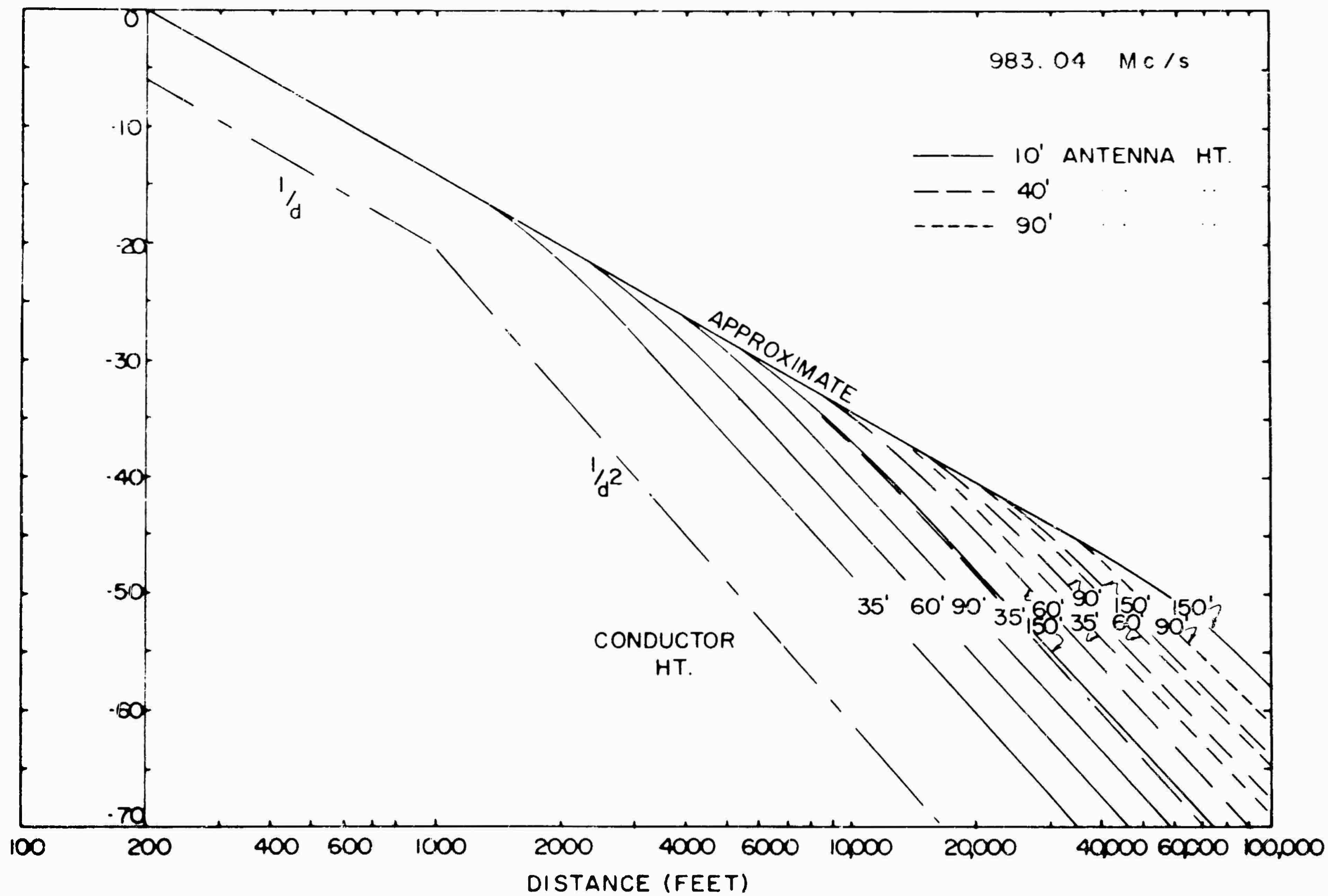

Fig. II-25-ATTENUATION OF FIELD WITH DISTANCE FOR HORIZONTAL DIPOLE PERPENDICULAR TO LINE AT 983.04 Mc/s

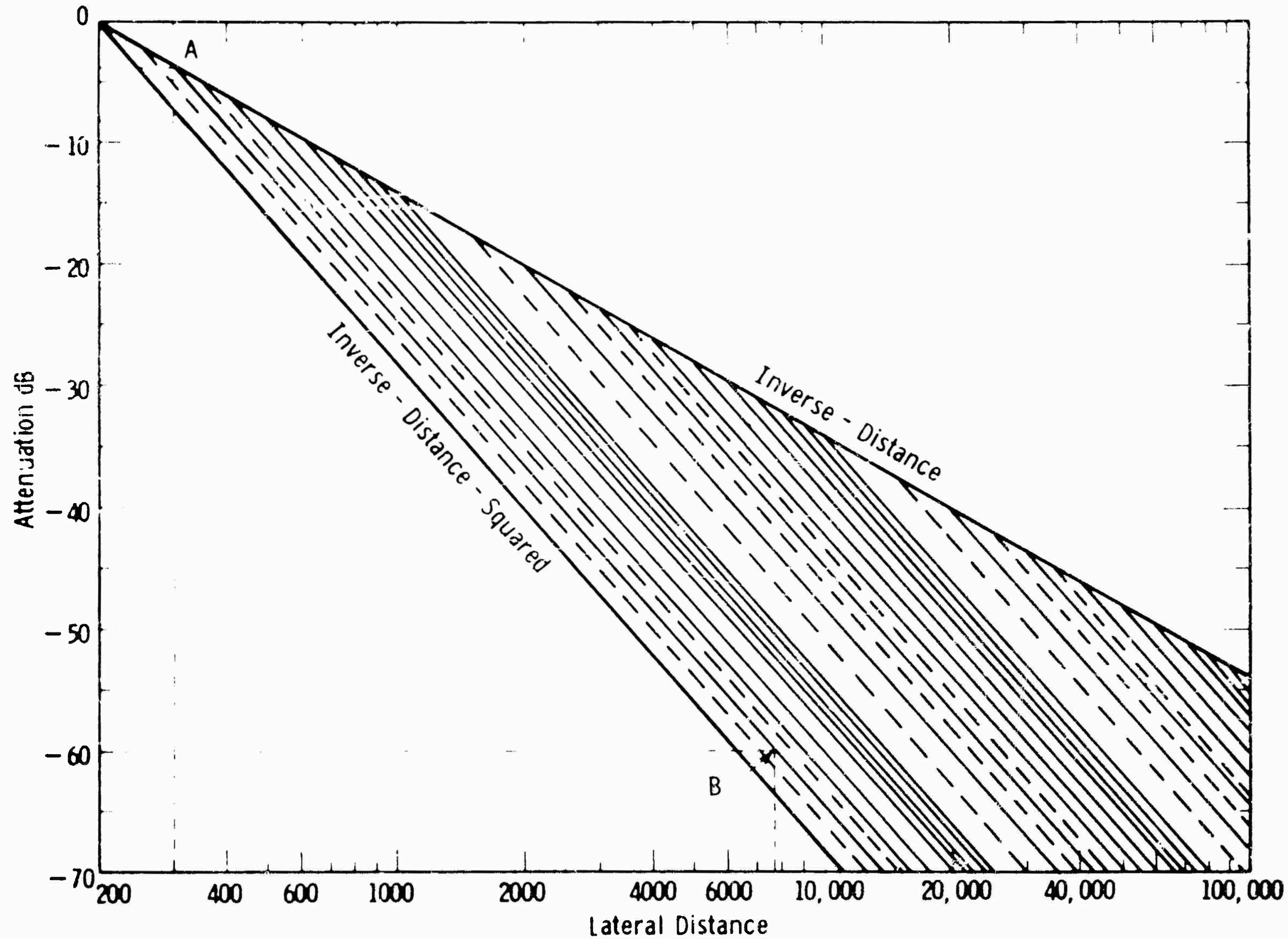

Fig. II-26— Generalized lateral attenuation

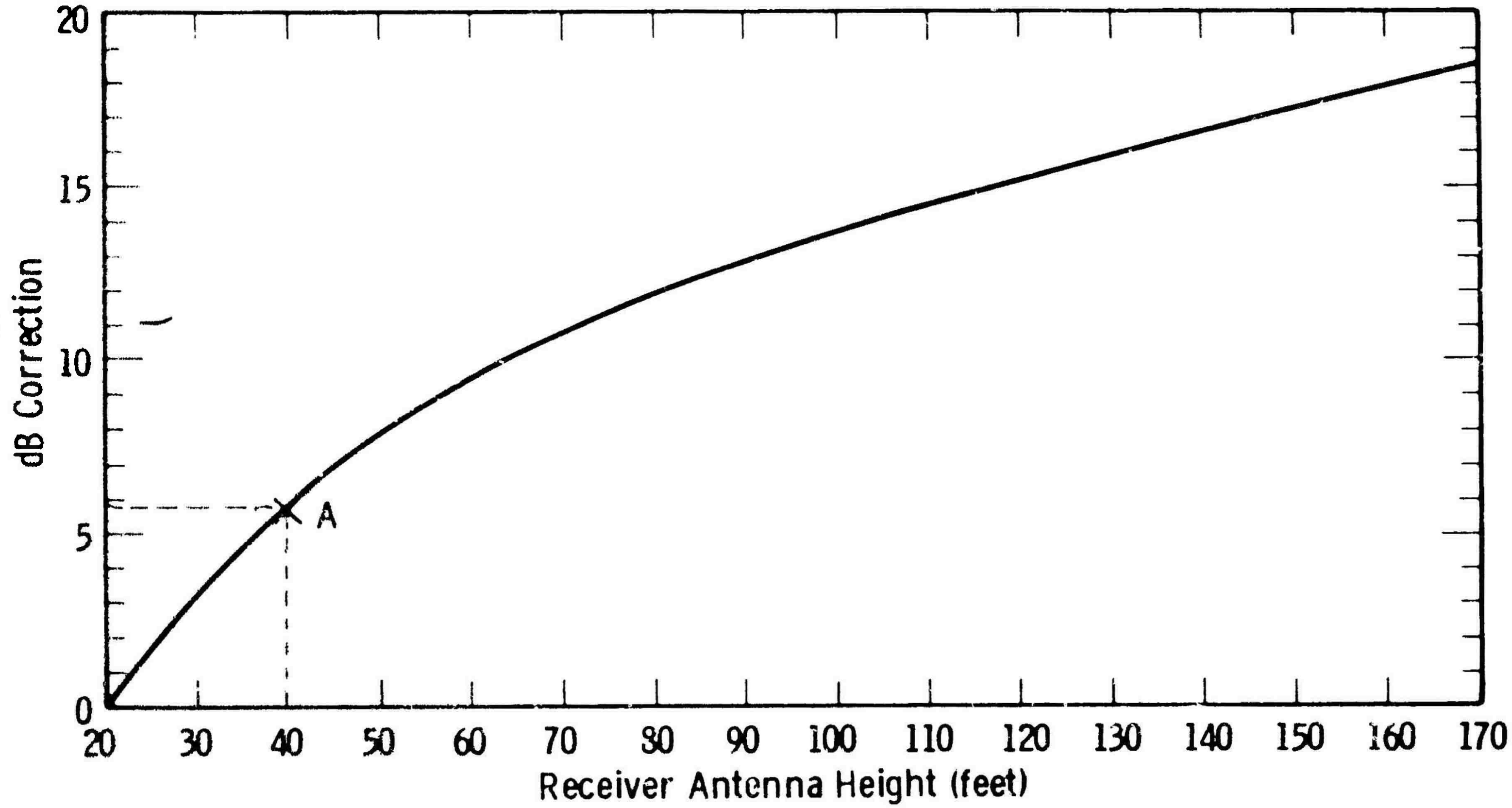

Fig. II-27— Correction for dipole antenna height beyond 2000 feet

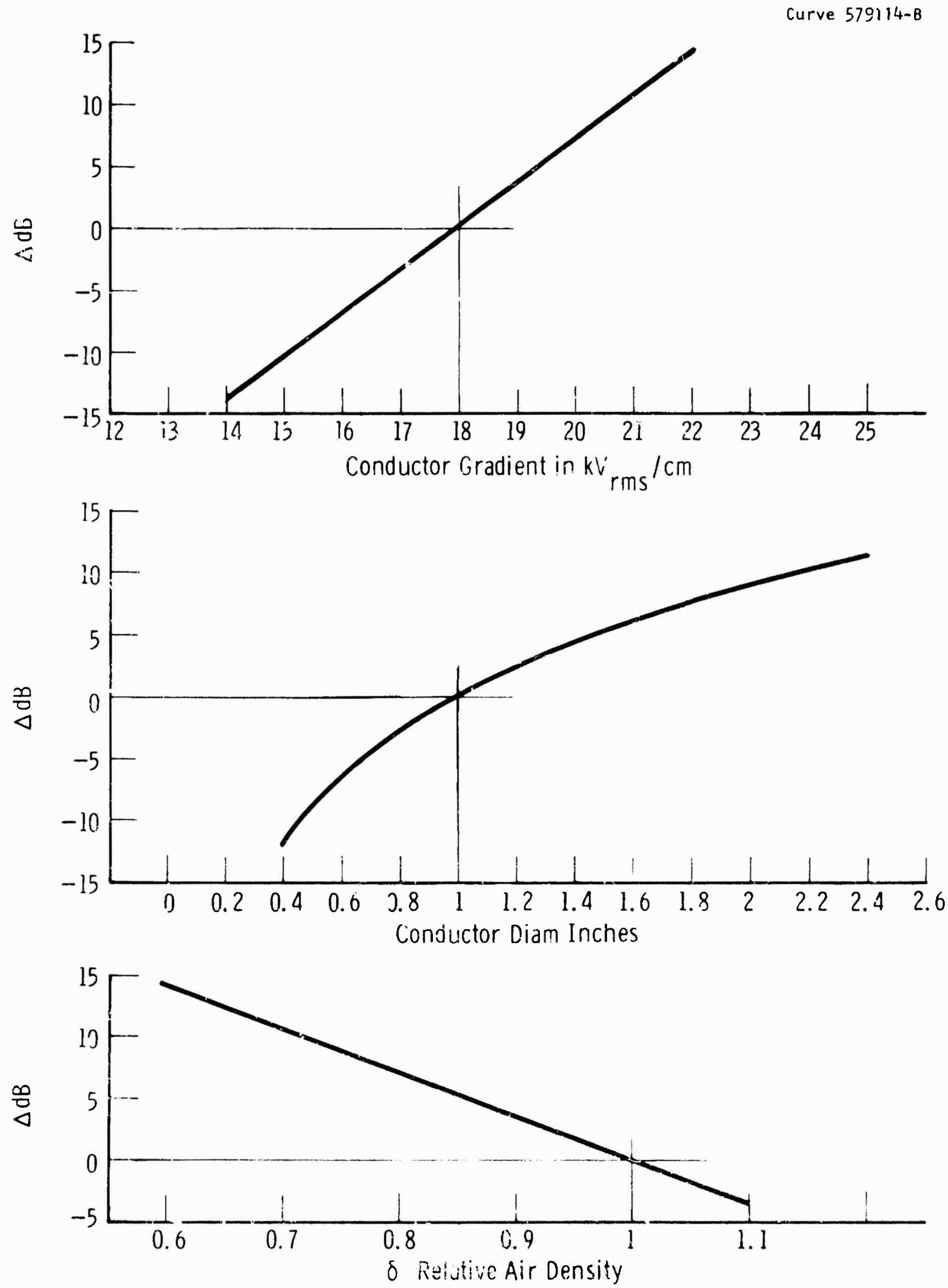

Fig. II-28– Changes in radio noise from line conductors in corona

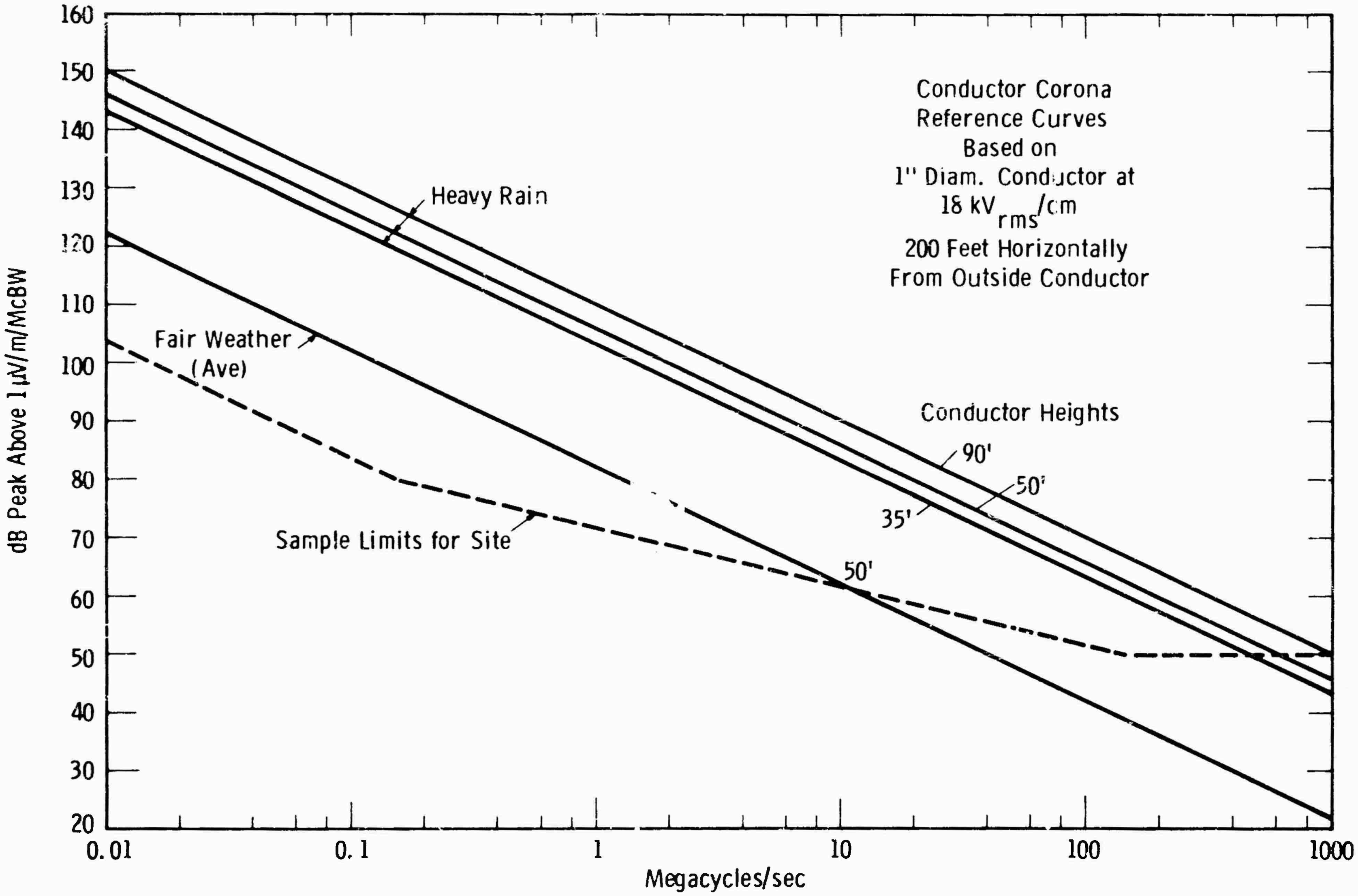

Fig. II-29—Prediction curves for conductor corona 110-345 kV lines with sample limit curve

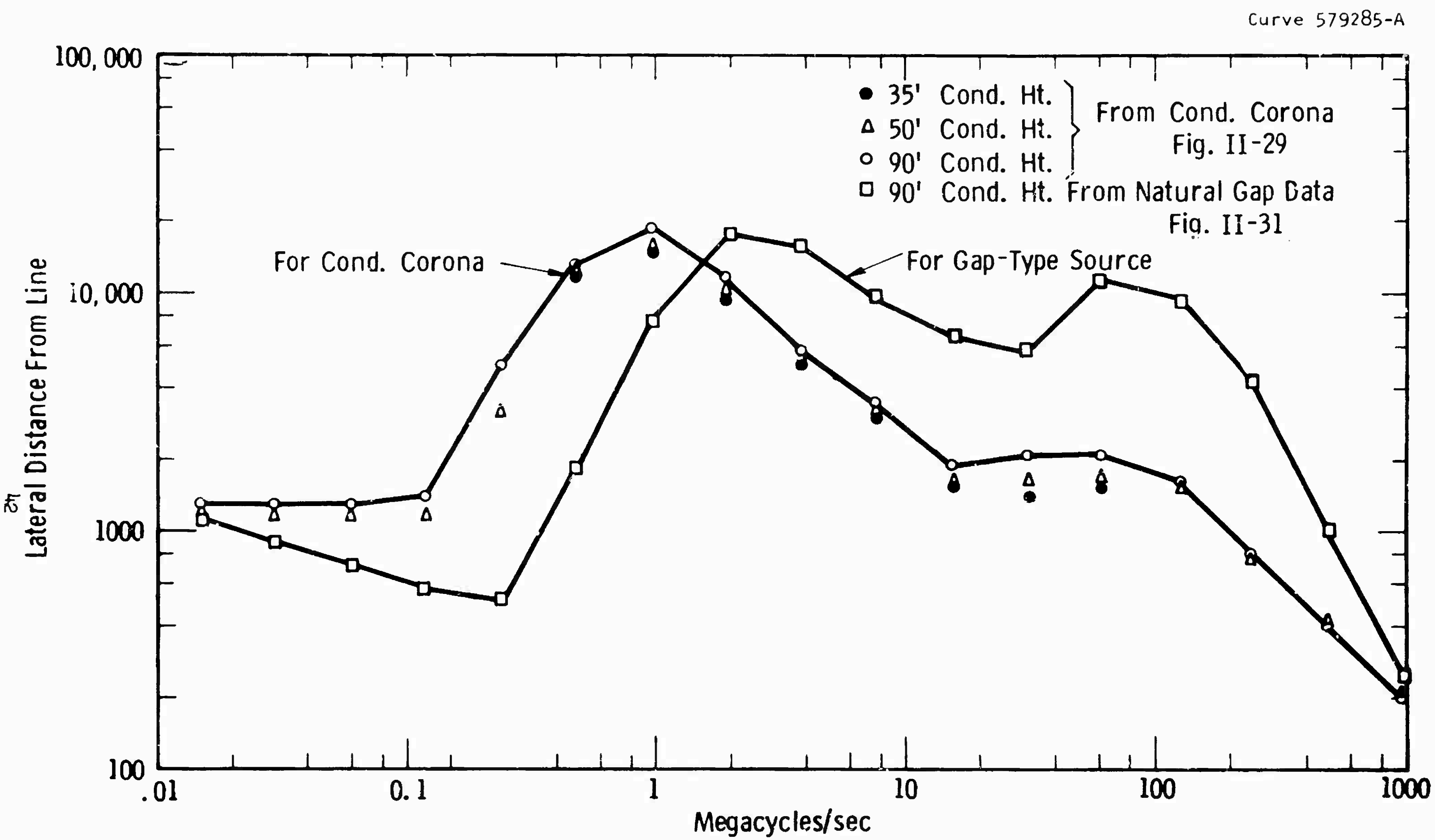

Fig. II-30— Site separation from power line for several conductor height

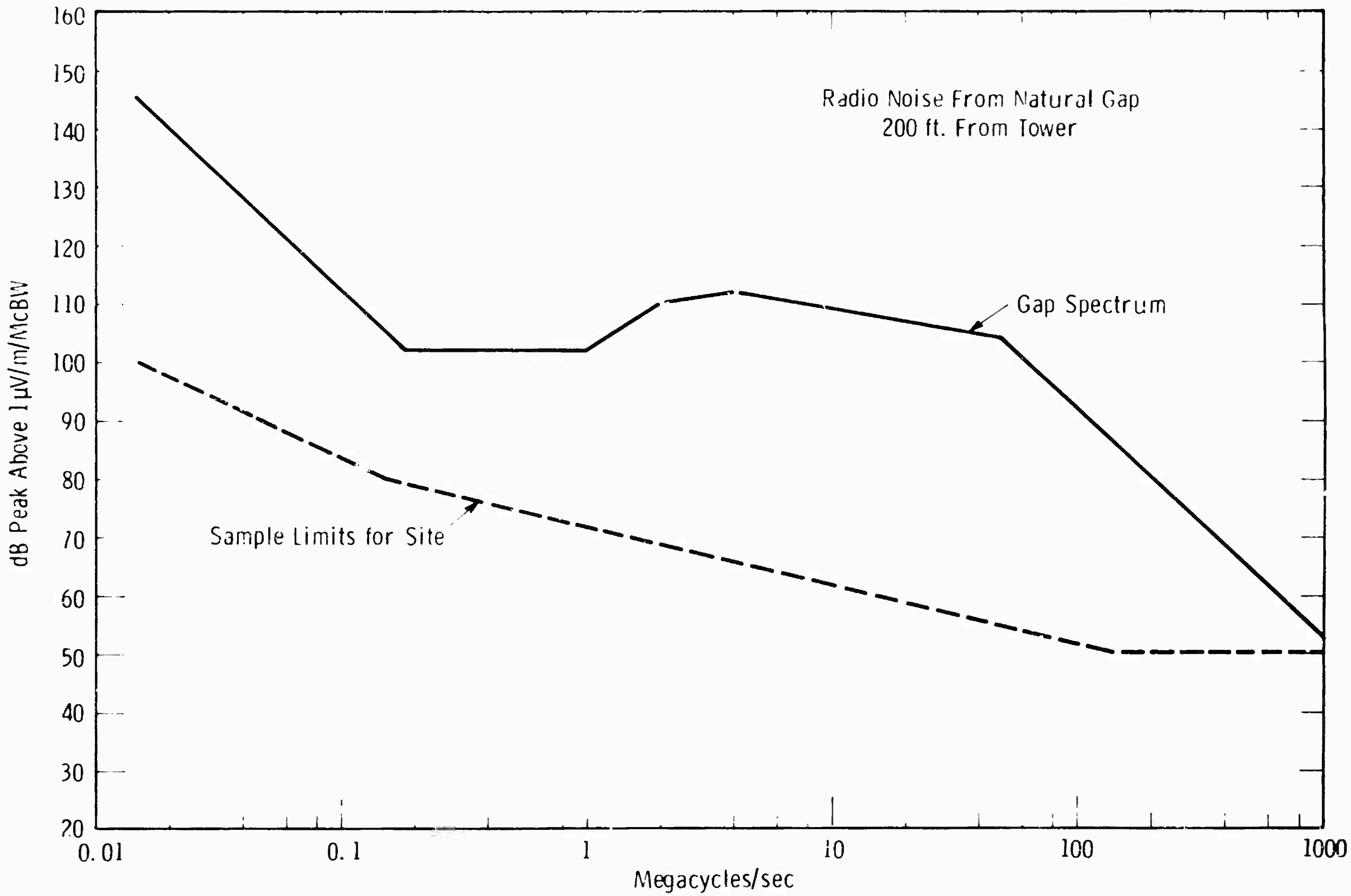

Fig. II-31—Prediction curves for natural gap-type radio noise at tower

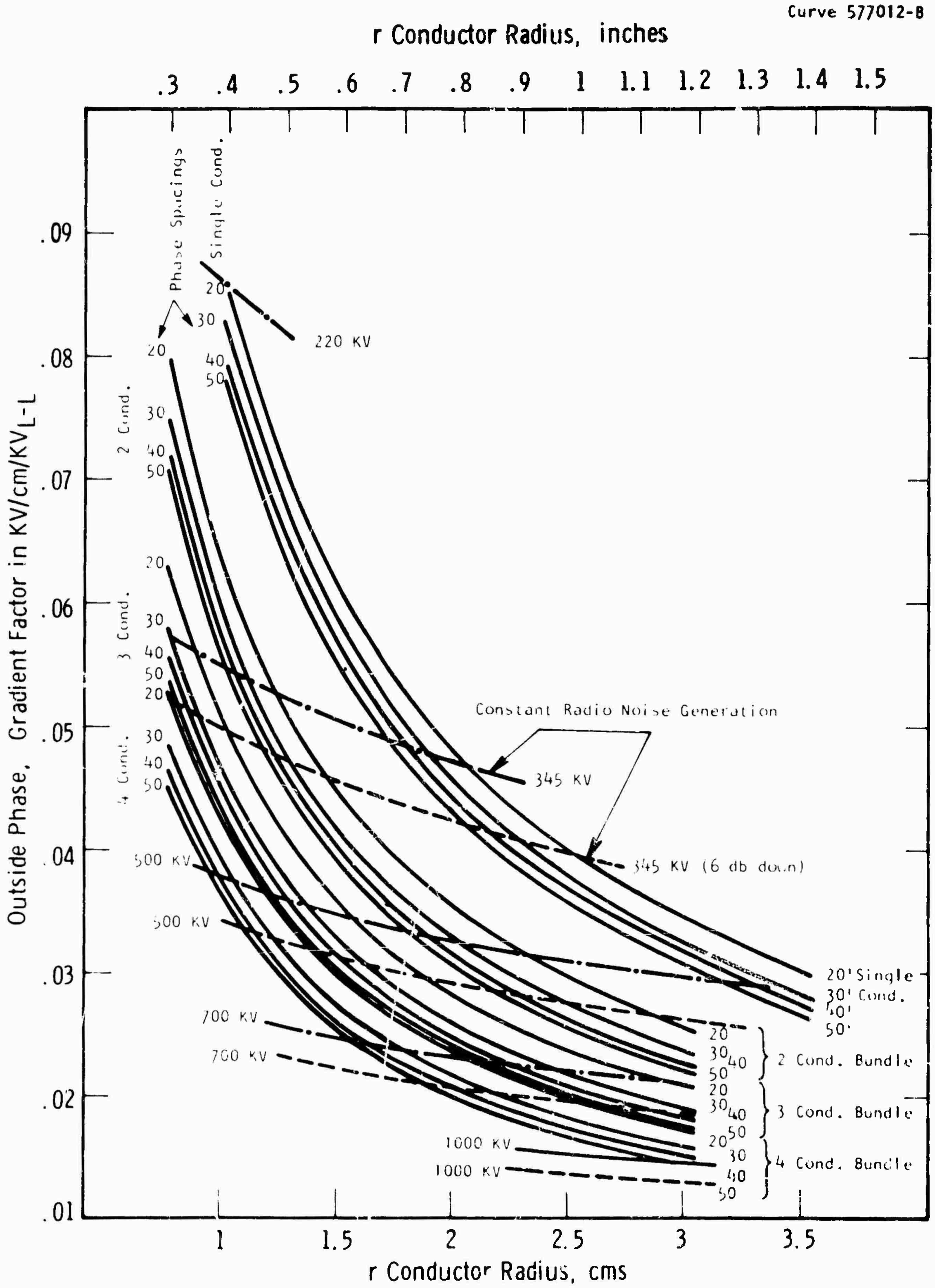

Fig. II-32— Outside phase gradient factors for single and bundle conductors

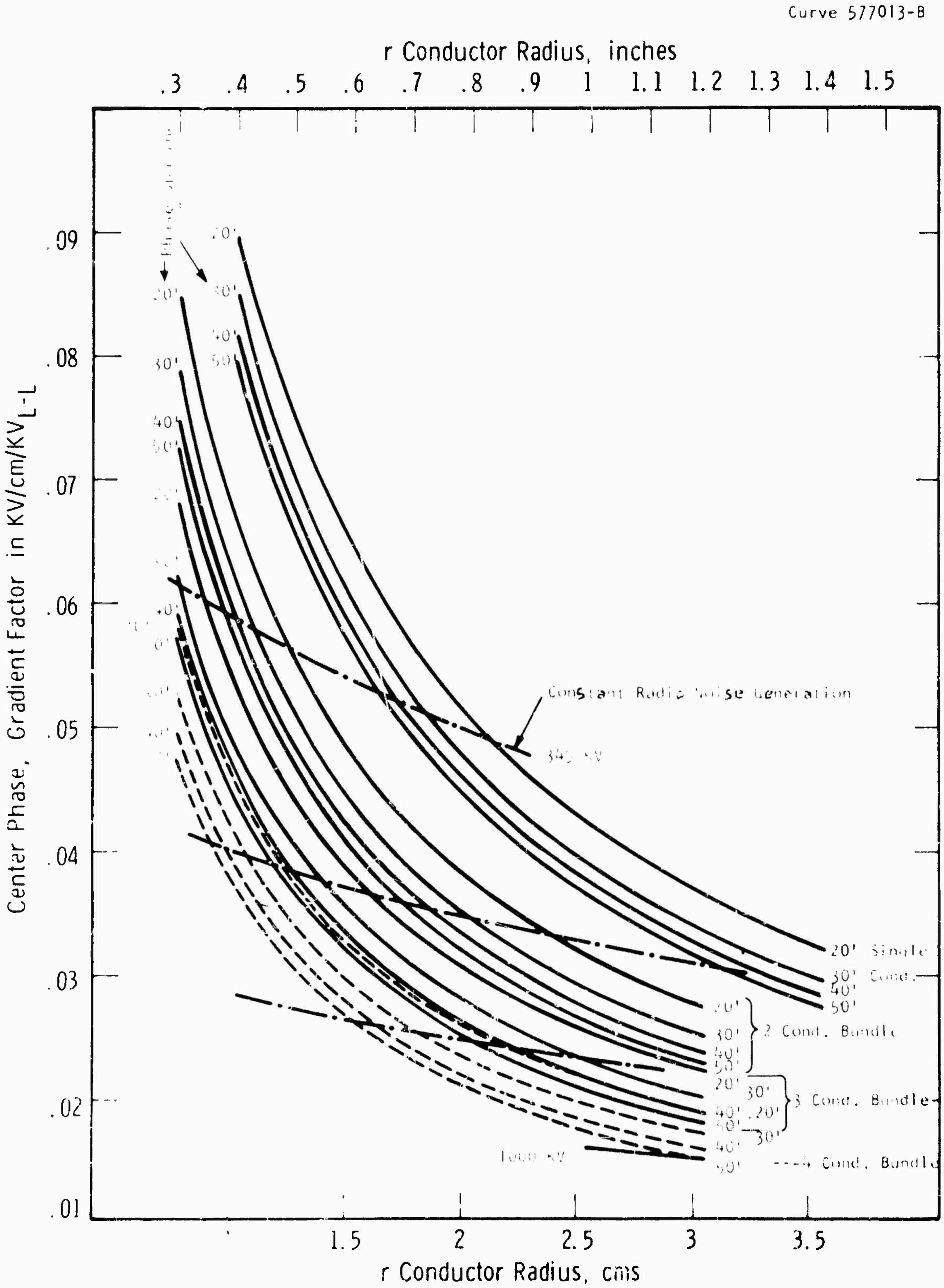

Fig. II-33— Center phase gradient factors for single and bundle conductors

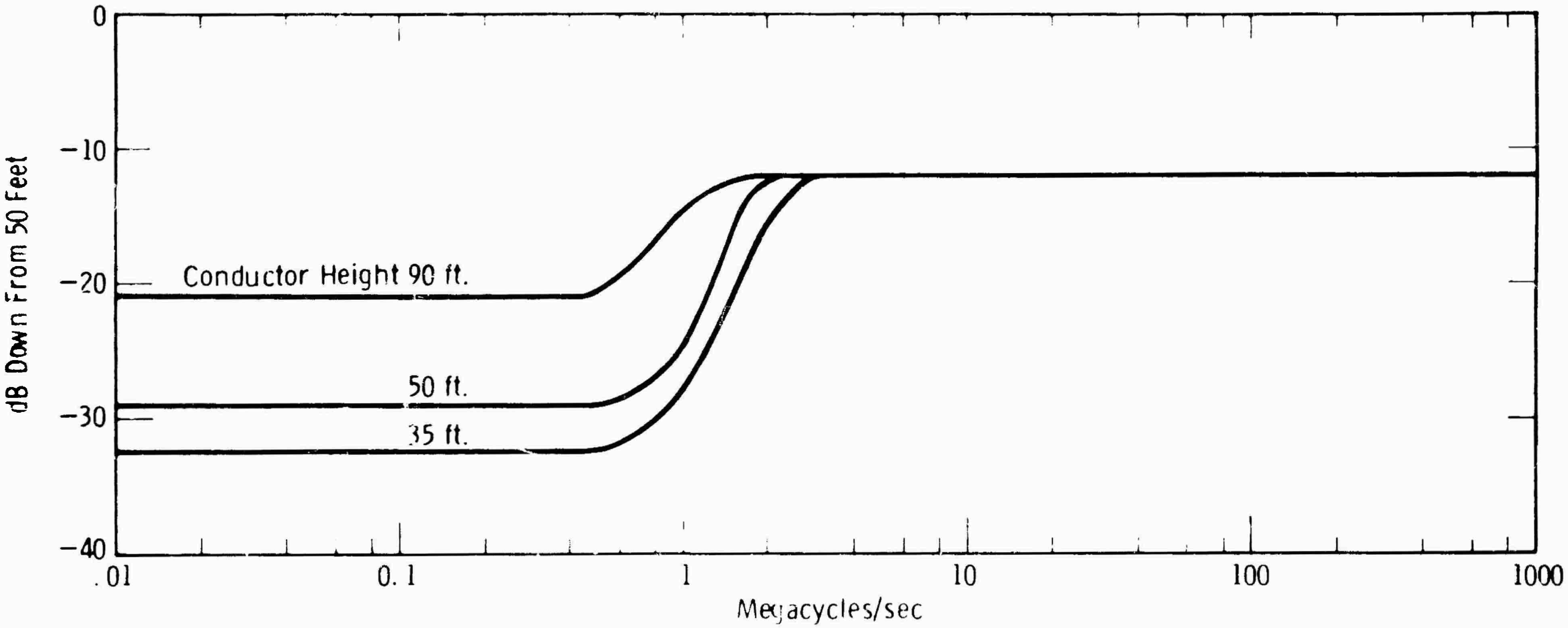

Fig. II-34-Correction from 50 foot lateral distance to 200 feet lateral distance

SUPPLEMENTARY

INFORMATION

TAB No. 69-23 1 December 1969

DISTRIBUTION AND AVAILABILITY CHANGES

IDENTIFICATION	*FORMER STATEMENT*	*NEW STATEMENT*	*AUTHORITY*
AD-812 267 Westinghouse Electric Corp., Pittsburgh, Pa. Final rept. Rept. no. 66-8E0-RADIO-R1-Vol-2, RADC-TR-66-606-Vol-2 Mar 67 Contract AF 30(602)-3822	No Foreign without approval of Rome Air Development Center, Attn: EMLI, Griffiss AFB, N. Y.	No limitation	RADC, USAF ltr, 14 Jul 69